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The Impingatron Seed Treater

L. A. KLOOR AND ALEX LANGE, JR.[1]

Received for publication February 1, 1960

Grower acceptance of sugar beet seed treatment has become more general during the past decade. To meet the increased demand for seed treatment, processors have had to keep abreast of developments in the use of more efficacious protectants and improved means of their application to seed by machines.

There are numerous types of seed treaters in current use. Most of these embody too many moving parts, occupy excessive floor space for installation and are costly to purchase. This paper represents a progress report to our industry in the development of a treater of unique design which holds promise of correcting the above disadvantages.

The original machine, conceived and designed for the blending of solids with solids or the impingement of liquid coating materials upon solids, was called an "Impingatron." As a blender it performed so well in the dispersion of the coating media that other applications of the machine's use occurred feasible to the inventor (1)[2].

The blender and the seed treater are very similarly constructed. The operating principle of both is the same. In the seed treater, to which we will confine all further discussion, the principle is one of spinning a tumbling blanket of seed through a finely divided mist of treating chemicals.

The tumbling blanket or layer of seed, conceivably one seed in thickness, is obtained by feeding the seed into the top center of a dished plate which rotates at 350 rpm. The seed is moved outward by centrifugal force toward the edge of the plate. Due to the rotation of this plate, the seed mass tends to roll and tumble as it approaches the speed of the plate. Concurrent with this imparted tumbling action of the seed, liquid treating material is fed at gravity head to two circular rotating feed rings. The purpose of these rings is to disperse the liquid evenly about the periphery of a dispersion disc. The rings and this disc rotate at 3000 rpm. The dispersion disc is provided with inclined fingers which atomize and give depth to the mist pattern. The treating liquid, reduced in particle size to a fine mist, is thrown upon the surface of the blanket of seed. The treated seed moves outward to the edge of the dished plate which is sealed, as well as driven, by a v-belt. The v-belt arrangement conveys the treated seed to a central discharge point.

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[1] Northern California District Agriculturist and Seed Processing Foreman, respectively, Holly Sugar Corporation.

[2] Numbers in parentheses refer to reference.

The machine is simple and has few moving parts, making it easy to clean and maintain. Power units consist of two 220-440 volt 60 cycle motors, one rated at 2 hp at 3600 rpm and one at ½ hp at 640 rpm. The seed and treating material feed devices are in the process of being designed and constructed for installation on the machine. The former will be a vane-type feeder with the vanes arranged in a helical plane rather than straight so as to reduce pulsations in the flow of seed. A Robbins & Myers "Moyno" pump will be used for metering and delivering the treating materials. The abrasive action of materials currently in use for the treating of sugar beet seed may alter such plans. A small efficient pump would be advantageous. However, accuracy throughout the life of the machine of measurements of both seed and treating materials is an absolute requirement. Then, too, some means of continuous agitation of the treating materials must be provided because these materials are all wettable powders, made up as water suspensions.

Some flexibility in the output of the machine is possible. As currently designed, the treater is capable of handling 3000 to 4000 pounds per hour of processed sugar beet seed. The over-all dimensions of the unit are: height, 36″; width, 40″; and length, 50″. These dimensions do not include seed and chemical metering equipment.

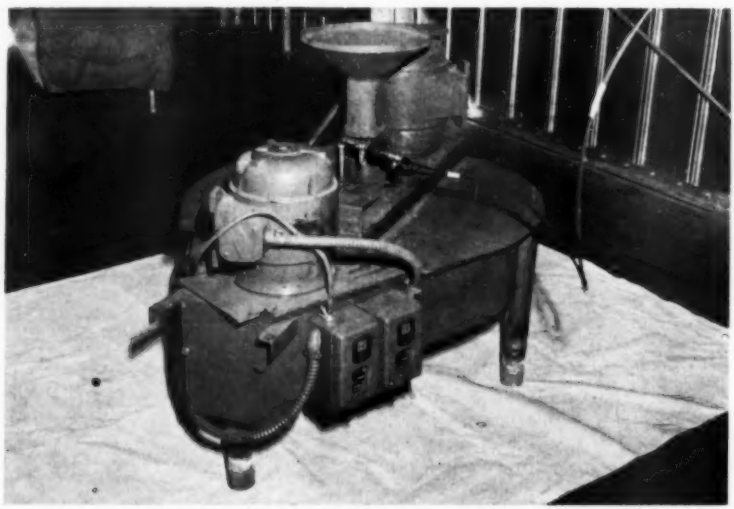

Figure 1.—Photograph of the Impingatron Seed Treater. The picture does not show the installation of the seed metering and treating material devices.

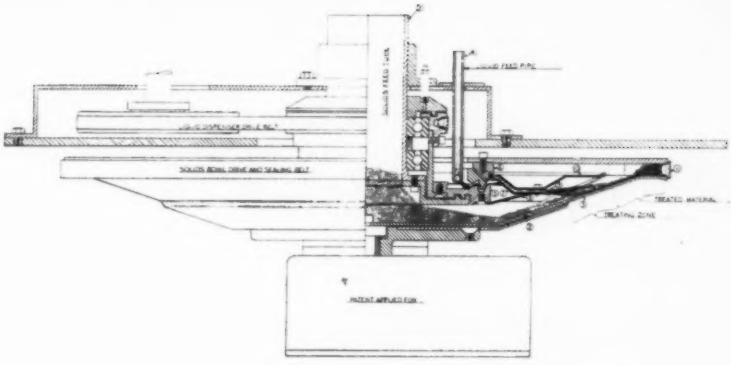

Figure 2.—Flow pattern in treating sugar beet seed. a). Seed is metered and gravity fed into the Solids Feed Tube (1) to the center of the Rotating Dished Plate (2). b). Centrifugal force of this plate causes the seed to be rolled and tumbled to the periphery of said plate. c). In so doing, the seed tends to form a thin layer of the thickness of one or two seeds as it reaches and travels thru the Treating Zone (3). d). Treated seed is contained by the seal which is formed by the V-belt 11 and discharges at a port formed by passing the V-belt over an idler pulley. e). Treating material in the form of a water-suspension of a wettable powder is metered volumetrically to give the required treatment dosage to the seed flowing through the treater. The material is fed by gravity into the Liquid Feed Pipe (4), from thence onto a Rotating Liquid Dispenser Plate travelling at high speed (8), f). Centrifugal force causes the liquid to spread out into a thin film in its passage from a liquid dispensing ring (5) (7). Upon reaching the periphery of the Liquid Dispenser Plate, the liquid is broken up into a fine mist by a series of inclined fingers which compose the periphery of the plate (9). The treating mist covers the treating zone area (3).

For the purpose of test runs of the Impingatron Seed Treater, the unit was temporarily installed at the Seed Processing Plant at Tracy, California. Installation was made adjacent to our regular seed treater. It was possible to employ our University Treater metering devices for the exact measurements of seed and dosage of treatment applied. Transfer of treated seed from the unit was effected by a horizontal scroll conveyor which discharged into the plant transfer equipment. The seed was bagged in normal fashion. Composite samples of treated seed were taken during each trial run. These samples were analyzed for efficiency of the treater and effectiveness of the treatment.

For the first trial run, a processed lot of monogerm seed was used. In order to have some comparison for evaluating the application, seed from the same lot was later treated in the University

Treater. The treatment used in all tests was Phygon XL (75% WP) @ 8 oz./100# seed, and Lindane (95% WP) @ 3 oz./100# seed, with a small amount of green dye added to visually determine the distribution of the treatment on the seeds.

The first trial run was, however, halted when a bearing on the chemical dispersion disc burned out. It was also noted during this run that the design of the labyrinths on the chemical dispersion disc caused some separation and build up of solid particles in the slurry. The machine was returned to the manufacturer for the necessary modifications.

When the treater was returned it had been fitted with an entire new set of working components. The liquid distribution labyrinths were made shallower to correct for the separation of the solid particles. Also, the pitch of the rotating dished plate was modified. Further bearing trouble was eliminated by the installation of ball bearings on the dispersion disc.

For the second trial run a processed lot of multigerm seed, Variety US 75, was treated. This trial run proceeded quite satisfactorily, except for a certain amount of seed "escape" from the rotating dished plate. This occurred where the v-belt carried the treated seed to the discharge point.

To eliminate the possibility of under-treated and over-treated seed at the beginning and end of each trial run, a three-way valve was installed in the feed line where the treating materials entered the Impingatron. The flow of liquid was diverted into a container until air had been cleared from the line and the flow of liquid was steady. The seed and the suspension were then allowed to enter the treater simultaneously.

Results and Discussion

Samples of the monogerm seed obtained from the first run of the Impingatron Treater along with comparative samples from the University Treater and a non-treated check were planted in soil infested with *Pythium ultimum*. The emergence and survival were calculated per 100 seed units and the results shown in Table 1.

From the results, it would appear that the seed treated in the University Treater produced as much emergence as indicated by the laboratory germination tests of 75 percent. Survival rate 12 days after planting was also fairly good. Both the emergence and survival of the seeds treated in the Impingatron were about 10 percent less than from the University Treater. Both treatments, however, were considerably better than the non-treated check.

Table 1.—Emergence and Survivors of Seed From the First Trial Run of the Impingatron as Compared to a Similar Treatment in the University Treater and a Non-Treated Check. Seed Was Planted into Soil Infested with *Pythium ultimum*.

Chemical Protection (Monogerm Seed)		
	Emergence	Survivors
	Per 100 Seed Units	
Untreated	30	8
Impingatron Treater	66	40
University Treater	77	50

Samples of the US75 seed from the second trial run along with the two checks also were planted in the soil infested with *Pythium ultimum*. These results are shown in Table 2.

A statistical analysis showed that there was no significant difference in emergence from the seed treated in the Impingatron and seed treated in the University Treater. The post emergence damping-off was a little greater with the seed treated with the Impingatron so that the final survival was about 10 percent less than from the University Treater. The analysis showed, however, the difference for survivors was not quite significant at the 5 percent level. It can, therefore, be assumed that there was little or no difference in the protection afforded by treatment of the US 75 seed with the two treaters. Both provided considerable protection as compared with the non-treated seed. The data in Tables 1 and 2 were furnished by the Division of Plant Pathology, University of California at Davis.

Table 2.—Emergence and Survivors of Seed from the Second Trial Run of the Impingatron Treater as Compared to a Similar Treatment in the University Treater and a Non-Treated Check. Seed Was Planted in Soil Infested with *Pythium ultimum*.

Chemical Protection (Variety US75)		
	Emergence	Survivors
	Per 100 Seed Units	
Untreated	9.4	1.1
Impingatron Treater	153.3	97.7
University Treater	146.6	107.2

To evaluate the uniformity of the application of the treating materials by the Impingatron, a visual analysis was made of the treated seed. The seed was divided into three catagories: a) under-treated, b) uniformly treated, and c) over-treated, depending on the coverage and the amount of treating material on each seed. Three 10 gram samples were analyzed and a mean determined. An identical test was run on seed from the University Treater in order to have a comparison. The results shown in Table 3 indicate that the majority of the seed from the Impingatron was not uniformly covered.

Table 3.—Uniformity of Treatment on Seed Treated in the Impingatron Treater as Compared to Seed Treated in the University Treater.

	Chemical Distribution (Monogerm Seed)		
	Under-Treated	Uniformly Treated	Over-Treated
Impingatron Treater	83.4%	15.2%	1.4%
University Treater	3.9%	96.1%	1 seed

Taking into account the results of the tests where the seeds were planted in infested soil it would appear that even though the seed treated in the Impingatron Treater lacked the uniform coverage of seed treated in the University Treater, it still provided sufficient coverage for adequate protection.

Summary and Conclusions

A new machine called the Impingatron, originally designed for the blending of materials, has been adapted for seed treating. The principle of its operation is centrifugal force. The seed falls on the center of a rotating dished plate and is carried outward toward the edge thereof. The liquid suspension of treating chemicals is fed from two rotating feed rings attached to the cover of the seed plate onto a dispersion disc. This disc which revolves about nine times as fast as the seed plate disperses the suspension evenly as a mist about its periphery. The mist is impinged upon the seed.

The advantages of this seed treater are its small space requirements, and its simplicity of construction which results in ease of cleaning and maintenance. These features make it ideal for permanent installation or portable seed treater. As the latter, it

could be transported in a pickup truck to small seed processing plants and to grower cooperative warehouses where adequate seed treating equipment is not available.

The results of two trial runs under actual commercial sugar beet seed treating conditions, demonstrated the place for such a machine in the industry. The treatment, although not being as uniformly applied as by some treaters now in use, does provide adequate protection for the seed under disease conditions found in the field

Further modifications of the Impingatron which are designed to improve its operating efficiency are planned. Trials will be continued in an effort to determine the place of the Impingatron in the treatment of processed sugar beet seeds (1).

Reference

(1) O'BRIEN INDUSTRIAL EQUIPMENT CO. Various communications.

Simulated Hail Injury to Sugar Beets[1]

M. M. Afanasiev, Stuart D. Lyda and I. K. Mills[2]

Received for publication February 5, 1960

Introduction

Hail storms occur in various parts of Montana causing considerable damage to sugar beets and other crops. At the present time there is no accurate information available concerning the effect of hail damage on the yield of sugar beets or on the sugar content. In particular, information is lacking on the effect of hail damage on yield when injury occurs soon after thinning or during the later part of the growing period. It is especially important to know whether beet roots continue growth through September, because it has an important bearing on determining hail damage during this month. It is possible that under favorable environmental conditions, beets may continue growth during this month, but under adverse weather conditions, practically no growth may occur during September.

Some work on simulated hail injury to sugar beets was conducted in Montana during 1946-1949 (1, 2)[3], but additional information is necessary to establish more accurate evaluation of this damage. The work reported in this paper was started in 1957 and continued during 1958 and 1959. The plan is to continue this study for at least five years. The present paper is a preliminary report of the results obtained during the first three years of this investigation.

Materials and Methods

The experiments were conducted at the Huntley Branch Station which is located in the Yellowstone Valley of Montana, about 20 miles east of Billings. Approximately two acres of beets were used in these studies each year. Beets were grown in two-year rotations with corn. Soil was usually fertilized for corn with manure (12-16 tons) and supplemented in the spring with 400 pounds of 15-20-0 fertilizer per acre. Sugar beets also were fertilized with manure in the fall and, during most of the years, 200 pounds of 0-45-0 fertilizer were added in the spring. Sugar beets were planted in rows 24 inches apart and the usual care was given to them during the growing season.

In producing simulated hail damage the following procedure was used:

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[1] Contribution from Montana State College, Agricultural Experiment Station, Bozeman, Montana. Paper No. 481, Journal Series.

[2] Department of Botany and Bacteriology, Montana Agricultural Experiment Station, Bozeman, Montana.

[3] Numbers in parentheses refer to literature cited.

1. Sugar beets were injured seven times during the growing season. The first injury was made in the middle of June and subsequent injuries at about 15-day intervals thereafter, with the last occurring in the middle of September.

2. On each date 25, 50, 75 or 100 percent of the beet foliage on each beet plant in different plots was destroyed. Each leaf blade was cut separately with scissors to remove the appropriate leaf area for the degree of injury. Approximately one-third of the leaves on each beet plant in every treatment was cut crosswise, one-third lengthwise, and one-third diagonally.

3. Each plot consisted of four 21.8-foot rows of beets (each linear 21.8-foot row, hereinafter called a "row," is equivalent to 1/1000 of an acre). All four rows of beets in a plot were subjected to the treatment; however, at harvest time, data were taken from only the two middle rows. Each treatment was applied to four replicated, randomized plots on every injury date. Four uninjured check plots were used for each date. Beets grown in defoliated plots were later compared to the beets in the check plots.

4. During the last week of September of each year the beets were harvested and counted, weights of tops and roots were determined for each of the 140 plots, and sugar analyses were made on samples drawn from each plot.

Discussion of the Results

In this discussion all weights and yields are average values for the appropriate treatment and injury date for the three years of the experiment.

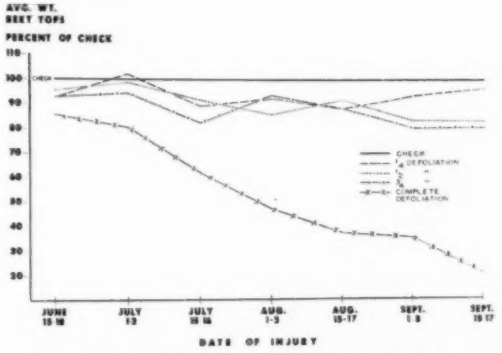

Figure 1.—The effect of various degrees of defoliation at different dates on the relative top weights of sugar beets at harvest (1957-59).

The tops of the check beets were, in general, heavier than the tops of beets subjected to injury.

The 25 and 50 percent defoliated beets produced similar top weights and were only slightly below those of the check. During September, however, weights of tops 25 percent defoliated beets approached the checks, while the tops of plants with 50 percent defoliation in the same period were lower in weight, and resembled those with 75 percent of the leaf area destroyed. In most cases, weights of tops of the 75 percent defoliated beets were slightly below those with 50 percent injury.

The greatest reduction in weight of tops with 25 percent defoliation occurred in the plants injured in middle of the growing season and was about 10 percent of the check. The greatest losses from the 50 and 75 percent treatments were observed for defoliations made during September and these were, respectively, about 16 and 20 percent of check beets.

The top weights of plants subjected to complete defoliation were much lower than for beets with lesser degrees of injury and continually decreased with later injuries. The greatest loss of weight from 100 percent defoliation occurred in plants injured late in the season and this loss was almost 80 per cent for the last defoliation.

In general, later injuries to the foliage were more influential in reducing the weight of beet tops than were early defoliations.

Sugar beets which were 25 percent defoliated produced about the same tonnage as beets of the check plots, regardless of the

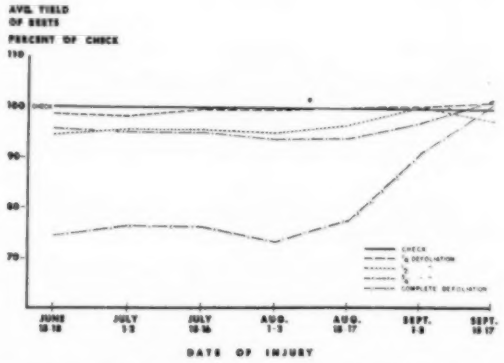

Figure 2.—Relative yields of sugar beets subjected to various degrees of defoliation on different dates (1957-59).

time of injury. The yields from plants which received 50 and 75 percent defoliation during the first five injuries were similar for each date of injury for both degrees of defoliation, and were only about 3 to 6 percent below the checks. Complete defoliation on the first five dates of injury considerably reduced the crop. Losses due to these treatments ranged from 23 to 27 percent of the checks.

Yield losses were fairly constant for a given degree of defoliation for all injuries from June though mid-August. Defoliations during September had little or no effect on yield.

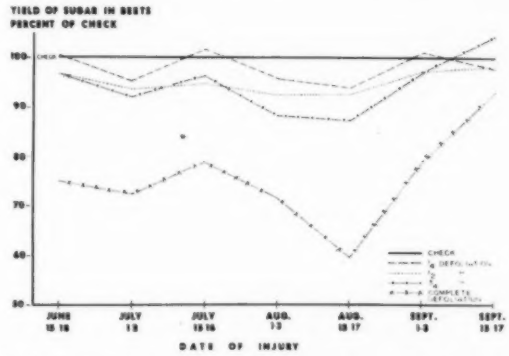

Figure 3.—Relative yields of sugar (on acre basis) in beets subjected to various degrees of defoliation on different dates (1957-58).

Yield of sugar was calculated on a basis of sugar production per acre.

The amount of sugar produced by beets with 25 percent defoliation varied only slightly from that of the check plants. The sugar yield of beets subjected to 50 and 75 percent injuries in general followed the pattern of 25 percent defoliated plants; however, the maximum sugar losses in these treatments was about 7 to 13 percent below that of the checks except for the September defoliations. Sugar yields from plants completely defoliated at various times throughout the season ranged from 21 to 41 percent below the checks with the exception of the final injury. Maximum damage, insofar as sugar production is concerned, occurred with the 100 percent, mid-August treatment.

It appears that 25, 50 and 75 percent defoliations throughout the season had little effect on the sugar production at harvest time. Beets with 100 percent injury showed a considerable loss in sugar for all defoliations except the last one.

Summary and Conclusions

The results show that tops of beets have great ability to recover from mechanical injury. However, the data also indicate that the recovery was almost never complete. Although the average top weights of injured beets at harvest time were usually always below those of non-injured beets, all degrees of defoliation up to and including 75 percent had only a slight effect in reducing weight of beet tops, and this reduction did not exceed 20 percent. The only substantial reduction in top weight occurred in completely defoliated beets, and later injuries had a greater effect in lowering top weight than did early treatments.

The 25 percent defoliations had practically no depressing effect on yield of beets per acre, while slightly reduced yields (6 percent or less) were obtained with the 50 and 75 percent levels of injury. Only beets defoliated 100 percent showed a considerable reduction in yield (23-27 percent). All September injuries had little influence on the yield of sugar beets.

These results show that if foliage destroyed does not exceed 75 percent, the effect of the injury on yield is slight. However, complete defoliation of beets in June, July and August produces a pronounced reduction in yield. It is possible that beets may develop many more leaves than they can utilize efficiently for normal growth of the root. If this is the case, slight to moderate defoliations may not impair greatly the continuous growth of beet roots.

Very little reduction in the percentage of sugar took place for all injuries with the exception of 100 percent defoliations.

In addition to the results reported here, further information was secured throughout the growing season on the number of beet leaves per plant, total area of beet leaves per plant, and top and root weights of beets. These results will be included in the final paper at the end of this study.

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(1) MORRIS, H. E. 1948. Simulated hail damage to sugar beets. Proc. Amer. Soc. Sugar Beet Tech. pp. 358-362.

(2) MORRIS, H. E. 1950. Simulated hail damage to sugar beets 1948-49. Proc. Amer. Soc. Sugar Beet Tech. pp. 302-304.

The Occurrence and Elimination of Saponin in Process Juice

J. R. JOHNSON[1]

Received for publication February 20, 1960

There are several processing means available to the beet sugar industry which affect the saponin content of refined sugar. They can be classified in two main groups: 1. Those which constitute major additions to, or departure from, the conventional process such as ion exchange or granular carbon; 2. Those which amount to minor changes in processing or which can be brought about through a change in process variables such as temperature, pH, flow, etc.

Ion exchange and granular carbon both can be very effective in the removal of saponin but represent a large capital investment.

The results presented in this paper point up the relative merits of a few of the less expensive possibilities the industry can use for the control of saponin. Until the use of ion exchange or other more positive methods of control are economically feasible the development of a cheap, reliable control method must be found. To accomplish this objective, three possibilities are shown, based upon the chemical and physical properties of saponin.

a. By taking advantage of the reduced solubility of saponin at low pH levels.

b. By formation of relatively insoluble calcium salts of saponin compounds.

c. The prevention of coagulation or crystallization of saponin by maintaining a high pH thus causing the saponin to pass through the process and be eliminated in the molasses.

The last method proved to be the most effective and is discussed in detail. The less effective methods are only briefly described in the following section.

Experimental

Full scale factory trials were carried out over periods of several days after the various means of saponin control exhibited some promise of success in laboratory experiments. The results of these tests are discussed as follow:

Trial No. 1 Reduction of Battery Supply pH

This trial consisted of reducing the pH of battery supply water to about 6.0 to 6.5 in an attempt to prevent or minimize extraction of saponin in the diffusion process. It was established in the laboratory that the extraction of saponin from beets increased when the battery supply water was in the alkaline range

[1] Manager of Research Laboratory, The Amalgamated Sugar Company, Twin Falls, Idaho.

and especially when it contained ammonia. This treatment did not significantly reduce saponin in process liquors and in granulated sugar.

Trial No. 2 Reduction of Standard Liquor pH

The next trial consisted of reducing the pH of standard liquor to 5.0 to 5.5 pH with sulfur dioxide ahead of first filtration. The reduced pH caused some saponin to precipitate and be removed by filtration. The pH of the filtrate was next adjusted to 7.0 with NaOH, filtered and sent to the pan floor. This procedure also failed to reduce the saponin content of standard liquor sufficiently to prevent co-precipitation or crystallization of saponin in the white pans.

Trial No. 3 Effect of Additional Lime on the Solubility of Saponin

It is possible to form insoluble calcium salts of saponin compounds. This is strongly pointed out by the fact that over 97 percent of the saponin entering the system in diffusion juice is eliminated during carbonation. The addition of milk of lime up to approximately 0.25% on beets at second carbonation resulted in only a minor reduction of saponin in Thin Juice. Pilot plant experiments in pre-defecation have shown a 50 percent reduction of saponin in thin juice when compared with conventional carbonation. Further work along this line may prove to be rewarding.

Trial No. 4 Effect of High pH on Solubility of Saponin

R. S. Gaddie (1)[2] demonstrated the potential of high pH boiling as a means of saponin control in white sugar. Gaddie added caustic soda to the white pan in rather large amounts in an effort to maintain the pan pH at 8.5. It was believed that by careful control of carbonation and sulfitration that the pH of the white pan could be maintained at satisfactory levels without the addition of caustic soda.

A study of the saponin content of factory juices correlated with the white pan pH over an entire campaign pointed to the fact that when the saponin content of standard liquor was less than 60 ppm on dry substance that the resulting sugar met the specifications of the soft drink industry providing the white pan pH was 8.0 or over.

Table 1 illustrates the ranges of saponin in factory liquors. Factories 3 and 4 produced low "floc" or low saponin sugar almost at will by maintaining the white pan pH at 8.0 or over. Factories 1 and 2 experienced difficulty in being able to control the saponin in sugar except during the periods when the saponin in standard liquor was less than 60 ppm.

[2] Numbers in parentheses refer to literature cited.

Table 1.—Distribution of Saponin in Liquors (1958-59 Campaign).

Factory	Saponin ppm on D.S.			
	1	2	3	4
Diffusion Juice				
High	9,193	5,926	4,756	3,860
Low	4,208	3,117	2,620	2,599
Average	6,429	4,709	3,516	3,282
Thick Juice				
High	173	206	159	191
Low	60	61	65	42
Average	103	110	105	83
Standard Liquor				
High	104	101	78	80
Low	51	48	44	26
Average	74	67	55	40
Number of Samples	90	95	150	150

It has been possible to maintain white pan pH over 8.0 by careful attention to carbonation and sulfitation. First carbonation alkalinity must be held as high as possible. With beets processed by The Amalgamated Sugar Company the optimum alkalinity is around 0.10. It is necessary to carry second carbonation alkalinity at .025 to .028 in order to use sufficient sulfur to stabilize the thin juice and to prevent a drastic pH drop through the evaporators. This has been accomplished by sulfuring to a thin juice pH of 9.0 to 9.2. Thick juice pH will then range from 8.0 to 8.4.

Table 2.—Effect of White Pan pH on Saponin in Sugar (Twin Falls Factory 1959-60 Campaign).

Date	pH White Fillmass	Saponin in Sugar ppm
12-26-59	8.5	1.3
12-27-59	8.3	1.7
12-28-59	8.5	2.0
12-29-59	8.6	1.7
12-30-59	8.4	1.3
12-31-59	8.7	1.3
1-1-60	7.1	7.9
1-2-60	6.8	4.9
1-3-60	7.1	7.0
1-4-60	6.6	6.0
1-5-60	7.2	7.0
1-6-60	7.1	7.9

Table 2 demonstrates the effect of white pan pH on the saponin content of white sugar. From December 26 to 31 all sugar produced met bottlers' standards. In the following period, the pan pH was deliberately reduced.

It is imperative that when a control such as this is in force certain conditions must be satisfied. Carbonation and sulfitation levels must be steady and uniform. Uneven control at this point can and will cause wide fluctuations in the thick juice pH. If the pH of thick juice drops below 8.0 for only a short time it is possible that the resulting sugar will be too high in saponin content for bottling purposes even though the pan pH indicates a satisfactory value. The failure of an entire day's sugar production to meet specifications has been traced to faulty operation for periods as short as 30 minutes at the carbonation of sulfitation stations. Continuous records of thick juice pH are more apt to pinpoint faulty operations than hourly laboratory data in a process such as this.

It is also necessary to establish upper limits for the concentration of saponin in sugar based on a quantitative analytical method and on a visual estimation. Assuming that most of the bottlers employ the Spreckels visual estimation method using acidified sugar solutions, a 24-hour development period and a strong light beam as their standard, the following study was made.

Four hundred and eighteen daily production sugar samples were analyzed for saponin by the visual Spreckels method and by a reliable quantitative method. The samples were selected in a random manner attempting to cover a wide range of saponin content in order to establish a reliable upper limit.

Table 3.—Frequency Distribution of Saponin in Sugar to Establish Limits of Acceptance.

Intervals Saponin ppm Quantitative	Spreckels Test Value (Visual)			
	Less than 1	1	Over 2	Total
0 - 2.1	157	6	1	164
2.2 - 3.2	111	22	5	138
3.3 - 5.9	18	41	22	81
Over 5.9	0	2	33	35
Total	286	71	61	418

If upper range is set at 2.1 ppm odds are 19 to 1 against putting sub-standard sugar on market.

At 2.6 ppm odds are 10 to 1 against putting sub-standard sugar on the market.

Table 3 is the frequency distribution of this study. A Spreckels test value of less than one showing only a slight haze at the most after 24 hours was chosen as the basis for acceptable bottlers sugar.

By setting the quantitative upper limit for acceptable sugar at 2.1 ppm the risk of placing a sub-standard sugar on the market is about 5 percent. By raising the limit to 2.6 ppm the risk increases to about 10 percent. However, if the sugar at 2.6 ppm is examined by the Spreckels test after 48 hours, a pinpoint development of floc will show up about 75 percent of the time.

At the start of the 1959 campaign the sugar rating standards were revised to include a penalty factor on sugar produced in certain factories if the saponin content exceeded 2.1 ppm.

The results have been gratifying in that at three factories, the to date average saponin content in sugar produced is 3.1, 2.3 and 2.4 parts per million. The percent acceptable bottlers sugar for the same factories is 57, 66 and 56% respectively for this year against an over-all average of about 38 percent a year ago and 15 to 20 percent in previous years.

The method of controlling saponin in sugar by high pH boiling is not without some inconsistancies. For example, one factory has been able to maintain satisfactory low levels of saponin in standard liquor which enables them to boil sugar at 7.5 pH. Opinions vary as to whether or not extraction of sugar is influenced adversely by high pan pH. At times, when the level of saponin soars to over 175 ppm in thick juice due to poor carbonation, the saponin level in sugar goes up to 5.0 ppm or more even when boiled from 8.5 pH liquors.

By using the techniques described in this paper it has been possible to supply bulk and liquid sugar outlets with an adequate amount of low floc sugar to allow multiple end-use of the product during peak seasons for bottling and canning deliveries.

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Compositional Changes in Diffusion Juices from Stored Sugar Beets

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For some time, the beet sugar processing industry has been aware of the problem of compositional changes in sugar beets during storage. Primary interest centered on the sucrose losses resulting from the effects of metabolic activity of beet tissue and invasive microorganisms. A further sugar loss was frequently noted in factory operation, since sugar recovery was usually poorer from stored than from fresh beets. Much of the pertinent literature on beet storage through 1950 in the United States has been summarized in Chapter 4 of *Beet Sugar Technology* edited by McGinnis (6)[2]. Since this time, new studies have been directed largely towards chemical control of beet respiration by enzyme inhibitors (10, 13, 14, 16, 19).

As a part of a program on sugar beet processing, we have conducted several small-scale storage studies to find whether significant chemical changes can be detected in the composition of beets stored under good conditions—that is, with adequate ventilation, humidification, and relatively little microbiological contamination. Basic information is necessary prior to studies of situations where abnormal respiratory or microbiological activity is a factor. Respiration rates (2, 18) for determination of sugar losses were not studied because the primary purpose was to see whether changes could be detected in the nonsugars of juices prepared from stored beets that might reflect changes in beet processibility or sugar recovery as a result of storage.

The small size and lack of replication of the storage samples used make it unwise to relate these results directly to commercial sugar beet storage practices. The results must be considered primarily as preliminary information for future work.

Methods and Materials

Beets and Storage Conditions. In early December 1956 commercially grown and freshly harvested sugar beets (derived from variety US 75) were obtained near Dixon, California. The beets were washed at the laboratory, dip-treated with a solution of fungicide (Orthocide W-50)[3], and divided into 10 storage samples.

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[1] Western Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture, Albany, California.

[2] Numbers in parentheses refer to literature cited.

[3] Mention of specific products does not imply recommendation by the Department of Agriculture over others of a similar nature not mentioned.

All samples weighed 130 lbs. and averaged 56 beets. Precautions were taken to see that beets were not exposed to wilting conditions.

The samples were packed in modified steel drums with removable covers—two samples per drum separated by a wire screen divider. After the cover was put on, water-saturated air was slowly passed through each drum for the duration of the experiment to maintain humidity and assure an adequate supply of oxygen for respiration.

Three drums were stored outdoors in the shade and two were stored at constant 34° F. Temperature of the outdoor beets was measured by a thermocouple inside one of the drums and average mean daily temperature was determined from a strip chart recording of the thermocouple readings. Average daily temperature fluctuation from low to high was about 15° F. The beets appeared to store well under these conditions. No weight losses were noted when the samples were removed and tissue turgor was good. After about a month, some of the beets showed evidence of sprouting and root growth. Traces of surface mold were also present after about a month in the outdoor series. The last sample remaining in the cold room was redipped in fungicide after 3 months. None of the samples showed appreciable rot infection in either series.

The 1955-56 beet samples were stored similarly except that the fungicide dip was omitted and 71° F. storage temperature was used instead of ambient. Mold and rot damage was more extensive than in 1956-57.

Juice Preparation: After a definite storage period, an entire 130-lb. sample was removed from a storage drum, cut into cossettes and mixed to provide a homogenous sample. Polarization (pol) was run on the cossettes and refractometric dry solids (RDS) on press juice. A small countercurrent diffuser was then used to prepare a diffusion juice (D-juice) from the cossettes. In addition, a "quick diffusion" (Q-juice) was made to see whether a simpler extraction procedure could be used to provide a representative sample of the extractable material in the cossettes. In this simple extraction 3 kg. of cossettes was extracted with 3 liters of initially boiling water in a water bath (70° C.) for 10 minutes with occasional stirring. The water was carefully drained and the process repeated with water at 70° C. These two extracts were composited and juice samples taken for analysis. The quick diffusion process appears to be a satisfactory means for obtaining the readily extractable materials in beets and is useful because of its simplicity and reproducibility.

Q-juice, D-juice, pulp, and cossette samples were sealed in tin cans, blast-frozen immediately and stored at —34° F. for analysis. Juices stored in this manner showed no changes in pol or RDS from measurements made on the fresh juices; stored pulp and cossette samples were used for moisture determinations only. For analysis juices were thawed, filtered and preserved with phenyl mercuric nitrate.

In 1955-56 juice samples were made only with the Olsen counter-current diffuser.

Chemical Analyses. Specific references for certain of the analyses are as follows: oxalated thin juice purity (4), amino N (15), betaine (9), total anions (11) raffinose (3), pectins (12). AOAC methods (1) were used for all other constituents. For this study, analysis for a particular constituent was run on all samples at the same time and results should be self-consistent even if the absolute value is uncertain.

Results and Discussion

In general, the results presented and discussed will be those obtained in the 1956-57 series for nearly ideal storage conditions. These represent a reasonable approach to the problem of chemical changes in beet and juice composition due to beet tissue metabolism.

The information obtained from the 1955-56 series was essentially the same as that from 1956-57 but effects due to spoilage were more pronounced.

Table 1 presents the 1956-57 beet data obtained from analysis of cossettes from each of the individual storage samples. It can be seen that pol, RDS and pol purity tend to decrease on storage

Table 1.—Analyses of Cossettes from 1956-57 Stored Beets.

Days Stored	Avg. Mean Temp., °F.	Pol. %	RDS. %	Purity (Corr. for Marc)	Sugar Loss Lbs/Ton/Day
0	----	16.95	20.56	86.5	----
9	56.5	16.94	20.42	87.0	0.02
22	52.8	16.15	19.65	86.2	0.73
29	53.0	16.20	19.93	85.2	0.52
42	52.7	16.07	20.15	83.6	0.40
63	52.0	16.21	19.83	85.7	0.24
90	54.5	15.54	19.51	83.5	0.31
61	34.0	16.82	20.14	87.6	0.04
111	34.0	16.02	19.77	85.0	0.17
187	34.0	15.46	18.80	86.2	0.16

at ambient temperature more rapidly than in a cooler environment. Although sugar is lost as shown in the lbs./ton/day column, the pol purities do not decrease as seriously as might be anticipated. The figures for sugar loss in lbs./ton/day are of the same order of magnitude noted in other studies (2, 6, 7, 18), but it is somewhat difficult to compare results obtained by one group of investigators with those of another using different beets, analytical methods, and sampling procedures. In 1955-56, the sugar losses at 34° F. were very close to those in 1956-57, and at 70° F. ranged about 1.0 lbs./ton/day for up to 55 days of storage.

The evident discrepancies that appear in Table 1 and the following tables would probably be resolved in experiments designed to provide greater replication. Although individual values in this series may not be exact, the trends are indicative of what might be expected.

Table 2 shows the purities of the juices prepared from the storage samples by both extraction procedures. True purity of raw Q-juice was calculated from chemical sucrose (corrected for raffinose) and oven dry solids. In general, the juice purity decreases with increasing storage time but the oxalated thin juice purities indicate that a thin juice well within the normal workable range could be obtained from any of these beet samples. The downward trend in the purity figures indicate that a somewhat decreased sugar recovery would be expected as a result of prolonged storage of beets.

Table 2.—Purity Analyses of Diffusion Juices from 1956-57 Stored Beets.

Days Stored	Avg. Mean Temp.	Q-Juice			D-Juice	
		Raw[1]	Raw[2]	Thin Juice[2]	Raw[2]	Thin Juice[2]
0	.....	93.3	92.3	93.1	90.3	92.2
9	56.5	96.5	90.4	93.1	91.3	95.1
22	52.8	94.3	90.5	92.4	89.2	91.4
29	53.0	92.6	90.9	91.9	89.7	91.5
42	52.7	92.3	90.5	91.3	88.3	90.5
63	52.0	93.9	89.7	91.3	88.5	91.2
90	54.5	88.1	87.7	87.7	86.2	87.2
61	34.0	93.9	91.2	93.1	90.5	92.9
111	34.0	91.4	90.7	92.9	90.0	91.5
187	34.0	87.4	87.8	89.9	89.3	89.3

[1] True purity.

[2] Apparent pol purity.

Table 3.—Chemical Analyses of Q-Juice of the 1956-57 Stored Beets[1].

Days Stored	Avg. Mean Temp.	Total Sugar (as Invert.)	Reducing Sugar[2]	Chemical Sucrose[2]	Total N + NO_3	Amino N	Amide N	Ammonia	Betaine	Anions[3]	Ash
0	——	93.8	0.3	93.4	0.80	0.37	0.09	0.06	1.51	3.14	2.50
9	56.5	97.2	0.6	96.5	0.66	0.29	0.06	0.04	1.25	2.87	2.34
22	52.8	95.1	0.6	94.3	0.72	0.34	0.08	0.05	1.39	3.05	2.40
29	53.0	93.7	0.9	92.6	0.75	0.33	0.07	0.08	1.52	2.96	2.34
42	52.7	94.1	1.0	92.3	0.82	0.37	0.07	0.08	1.39	3.33	2.62
63	52.0	95.4	1.4	93.9	0.72	0.31	0.08	0.05	1.32	2.81	2.33
90	54.5	93.8	5.6	88.1	0.75	0.36	0.09	0.05	1.52	3.13	2.83
61	34.0	94.9	0.6	93.9	0.67	0.28	0.07	0.05	1.48	3.00	2.27
111	34.0	93.7	2.1	91.4	0.76	0.32	0.08	0.05	1.33	3.17	2.69
187	34.0	94.6	6.8	87.4	0.58	0.23	0.06	0.04	1.46	3.14	2.67

[1] Calculated as weight % of oven dry solids.

[2] Corrected for raffinose.

[3] Calculated for average equivalent weight of 60.

Table 3 shows the chemical analysis of Q-juice samples, calculated as weight-percent of total solids for particular constituents. The interpretation or significance of these data is not unequivocal because of the single sample variability of beets and possible analytical uncertainties. The most obvious change occurs in the reducing sugar-sucrose relationship (17) with reducing sugar accumulating at the expense of sucrose. The increase in reducing sugar seems to result from a normal metabolic change in healthy tissue and is not associated only with spoilage. Note that the total sugar percentage stays reasonably constant. The other analyses presented show no other clear-cut, unambiguous trend. These analyses represent juice constituents only, and no material balance has been made between pulp and juice, as for example with ash or total N, which should remain constant. From the slight tendency for total N, amino-N, and amide-N in juice to decrease on storage, it is possible that some nitrogen has been incorporated into non-diffusible proteinaceous cell wall material as storage proceeds. Betaine appears to remain fairly constant. The total anions do not seem to accumulate to any extent since many of them are active metabolic intermediates. Treatment of the data by taking ratios between constituents does not improve or clarify the interpretation of these results. The analytical data indicate that, apart from the reducing sugar-sucrose change, little change in chemical composition of juices from these stored beets was apparent. However, the increase in reducing sugar would presumably increase lime-salt and color formation during processing.

Table 4.—Accumulation of Raffinose in Beets Held at Low Temperature, D-Juice, 1956-57.

Days Stored	Avg. Mean Temp. °F.	Raffinose[1]
0	.....	.13
9	56.5	.19
22	52.8	.22
29	53.0	.15
42	52.7	.21
63	52.0	.22
90	54.5	.19
61	34.0	.56
111	34.0	.51
187	34.0	.48

[1] Calculated as weight % on RDS.

Table 4 shows raffinose data on D-juice from stored beets. Note that the level of raffinose increased approximately 3-fold in beets stored at near-freezing temperatures over beets whose average mean storage temperature was about 20° F. higher. Obviously, accumulation of raffinose would have an adverse effect on sugar recovery from beets stored in cold areas, provided this change had not already taken place by the time of harvest. Previous workers have noticed with field beets that raffinose increases significantly when harvest is delayed if the mean minimum is near 34° F. or below (8). The sharp temperature dependence discovered in the present study and its significance should be studied further.

Table 5 shows that non-dialyzable juice-colloids did not change significantly in filtered clarified juices from beets not exposed to serious microbiological attack. The juice samples used for these determinations were frozen, thawed and filtered before dialysis. These analyses show that no serious differences in rates of sedimentation or filtration of first-carbonation muds should be observed because of soluble colloids.

Table 5.—Analyses Showing the Amounts and Partial Composition of Diffusion Juice Colloids, 1955-56.

Days Stored	Avg. Mean Temp. °F.	Total Colloids[1]	Protein[1,2]	Pectins[1,3]
0	....	1.40	0.21	0.49
13	69	1.45	0.21	0.44
23	69	1.48	0.17	0.42
48	69	1.54	0.24	0.43
57	34	1.66	0.26	0.46
161	34	1.37	0.22	0.32

[1] Calculated as weight % on oven dry solids.

[2] Calculated as total N × 6.25.

[3] Calculated as anhydrouronic acid.

Conclusions and Summary

The results of this preliminary work point up the need for thorough, carefully designed and replicated studies of beet storage problems, particularly in regard to processing quality of the juices obtained from beets that have not been severely damaged. The present data indicate that beet and juice quality need not deteriorate seriously during prolonged storage, even though sucrose losses do occur. Although a cold storage environment is

favorable from the standpoint of control of beet metabolism and microorganisms, it appears to promote an undesirable accumulation of raffinose.

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Viable Diploid, Triploid and Tetraploid Hybrids Between Beta Vulgaris and Species of the Section Patellares

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Introduction

Hybrids of *B. vulgaris* L. × species of the section *Patellares Tr.* were obtained in the last decade by several American and European investigators. As a rule these hybrids failed to grow. They died in the seedling stage after having developed cotyledons and the first pair of rudimentary leaves. Only occasional hybrid plants survived and developed into flowering plants. All viable hybrids thus far obtained have been diploid, coming from crosses of diploid beets from the section *Vulgares* Tr. with *B. webbiana* Moq. or with *B. procumbens* Chr. Sm.

Stewart (28)[2] obtained a single viable hybrid between the sugar beet (*B. vulgaris*) and *B. procumbens.* Gaskill (4) succeeded in obtaining 5 viable hybrid plants which reached the flowering stage from crosses of Swiss chard (*B. vulgaris*) × *B. webbiana* and 1 hybrid plant from mating Swiss chard × *B. procumbens.* All hybrids with *B. patellaris* Moq. were inviable. Oldemeyer (15) obtained viable hybrids from the following crossings: *B. macrocarpa* Guss. (section *Vulgares* Tr.) × *B. webbiana;* California dwarf (*B. maritima* L.) × *B. procumbens;* and *B. atriplicifolia* Rouy (section *Vulgares* Tr.) × *B. procumbens.* One hybrid plant (*B. macrocarpa* × *B. webbiana*), reached the flowering stage. No viable hybrids were obtained from crosses of the sugar beet and *B. patellaris.* Oldemeyer and Brewbaker (16) reported 15 flowering plants from crosses of Detroit Dark Red table beets with *B. webbiana* and *B. procumbens* and 2 flowering plants from the mating of the Turkish wild beet (*B. maritima*) and *B. procumbens.* Rietberg and Hijner[3] in the Netherlands obtained one viable hybrid plant from a hybridization of the red table beet to *B. procumbens.*

The species *B. vulgaris,* as well as its subspecies and races, can be comparatively easily crossed with species of the section *Patellares.* Species isolation is accomplished in this case, as in other widely-related species, by the barrier of inviability and sterility of F_1 hybrids (Stebbins, 26, 27; Brock, 1).

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[2] Numbers in parentheses refer to literature cited.

[3] Personal communication.

A study of the possibilities of overcoming the barrier of inviability and sterility by increasing the diversity of the races involved in hybridization and the application of polyploidy is presented in this paper.

Materials and Methods

Hybridization of different beet races of the species *B. vulgaris* and wild beets resistant to nematode of the section *Patellares* has been conducted for several years. The seed obtained was planted in the spring of 1958. Viable F_1 plants were obtained on a large scale. Hybridization was conducted on different ploidy levels. Diploid sugar beets, fodder beets, red table beets, and Swiss chard, as well as tetraploid sugar beets and tetraploid Swiss chard, were used as female parents. Only self-sterile plants were used as females; self fertiles or male steriles were never involved in hybridization. The pollinators were 2 diploid species, *B. procumbens* and *B. webbiana*, and a tetraploid species *B. patellaris*.

Hybridization was effected by enclosing branches of self-sterile plants in bags and pollinating by replacing these bags with bags containing pollen collected from wild beets. Female plants were pollinated when two-thirds of their flowers were open. Pollination was repeated two or three times at intervals of a few days.

The number of chromosomes was counted in the root tips of all viable hybrids. The root tips were fixed in chrome-aceto-formol, dehydrated, imbedded in paraffin, sectioned and stained with iron hematoxylin. Some ordinarily inviable diploid, triploid, and tetraploid hybrids were grafted and developed into tall, bushy plants. Photographs of hybrid plants, flowers, inflorescenses and fruits are presented.

Experimental Results

Characteristics of F_1 diploid, triploid, and tetraploid hybrids

Hybrid seedlings were distinguished from non-hybrids by later germination, narrow cotyledons, red hypocotyl, and very often by red spots on the cotyledons and the first leaves. The percentage of hybrid seedlings varied in different matings from 0 to 100. In 43 of 64 matings, the proportion of hybrid seedlings exceeded 50 percent. Diploid, triploid, and tetraploid hybrid seedlings were obtained (Table 1). The diploid hybrids arose from mating diploid plants of *B. vulgaris* with plants of the diploid species *B. procumbens* and *B. webbiana*. The tetraploid hybrids were obtained from crosses of tetraploid *B. vulgaris* (4*n* sugar beets and 4*n* Swiss Chard) with the tetraploid *B. patellaris*.

Table 1.—F_1 Hybrids between Races of *Beta vulgaris* and Nematode-Resistant Species.

Progeny Number	Female Parent (*B. vulgaris*)	Pollinator	Number of Seedlings		Percent Hybrid Seedlings	Ploidy Level of F_1 Hybrids	Viability of Hybrids		
			Non-hybrid[1]	Hybrid			Lethal	Viable	Low Viability
2*n* sugar beets:									
26	Self-sterile mm N15	2*n B. procumbens*	1	0	0	2n	x		
27	Self-sterile mm N15	2*n B. procumbens*	10	82	89.1	2n	x		
32	US 22/3	4*n B. patellaris*	23	41	64.0	3n	x		
33	US 35/2	4*n B. patellaris*	0	27	100.0	3n	x		
34	Self-sterile mm N15	2*n B. webbiana*	30	10	25.0	2n	x		
45	US 35/2	2*n B. webbiana*	35	15	30.0	2n	x		
47	US 22/3	2*n B. procumbens*	10	28	73.6	2n	x		
51	Klein E	2*n B. webbiana*	5	15	75.0	2n	x		
52	US 35/2	4*n B. patellaris*	0	56	100.0	3n	x		
53	Janash	2*n B. procumbens*	6	13	68.4	2n	x		
55	US 22/3	4*n B. patellaris*	4	78	96.3	3n	x		
59	US 35/2	2*n B. procumbens*	95	10	9.5	2n	x		
2*n* fodder beets:									
16	Ovana	2*n B. webbiana*	1	33	97.0	2n	x		
41	Barres	2*n B. procumbens*	15	56	78.0	2n	x		
2*n* red table beets:									
18	Egyptian	2*n B. webbiana*	11	45	80.3	2n	x		
38	Detroit	2*n B. webbiana*	5	0	0	2n	x		
42	Egyptian	4*n B. patellaris*	10	62	86.1	3n	x		
43	Detroit	2*n B. procumbens*	22	60	73.1	2n	x		

TABLE 1.—CONTINUED ON PAGE 218.

[1] The non-hybrid seedlings were due to contamination during the exchange of bags.

Table 1.—(Continued from page 217)—F_1 Hybrids between Races of *Beta vulgaris* and Nematode-Resistant Species.

Progeny Number	Female Parent (*B. vulgaris*)	Pollinator	Number of Seedlings		Percent Hybrid Seedlings	Ploidy Level of F_1 Hybrids	Viability of Hybrids		
			Non-hybrid[1]	Hybrid			Lethal	Viable	Low Viability
2n Swiss chard:									
4	Lyon	*4n B. patellaris*	10	0	0	3n	x		
5	Lyon	*2n B. webbiana*	4	35	89.7	2n	x		
13	Silber	*4n B. patellaris*	53	0	0	3n	x		
17	Lyon	*2n B. webbiana*	52	41	44.0	2n		x	
29	Lyon	*2n B. webbiana*	10	56	84.8	2n	x		
35	Fordhook Giant	*4n B. patellaris*	45	52	53.6	3n	x		
48	Gruner Schaitt	*4n B. patellaris*	0	65	100.0	3n	x		
49	Lukullus	*2n B. procumbens*	21	82	79.6	2n	x		
54	Glatter Silber	*2n B. procumbens*	2	36	94.7	2n	x		
58	Lyon	*4n B. patellaris*	10	10	50.0	3n	x		
64	Lukullus	*2n B. webbiana*	25	10	28.5	2n	x		
4n sugar beets:									
2	US 35/2	*4n B. patellaris*	0	26	100.0	4n	x		
8	US 35/2	*4n B. patellaris*	0	23	100.0	4n		x	
9	US 22/3	*4n B. patellaris*	15	5	25.0	4n		x	
19	US 35/2	*4n B. patellaris*	5	14	73.1	4n		x	
20	US 22/3	*4n B. patellaris*	1	65	98.4	4n	x		
23	US 22/3	*2n B. procumbens*	1	3	75.0	3n	x		
31	US 35/2	*4n B. patellaris*	0	11	100.0	4n		x	
36	Self-sterile mm N15	*4n B. patellaris*	10	35	77.7	4n	x		
37	US 35/2	*2n B. procumbens*	45	25	35.8	3n	x		
46	US 35/2	*2n B. procumbens*	20	68	77.2	3n	x		
50	US 22/3	*2n B. webbiana*	5	0	0	3n	x		
61	US 35/2	*2n B. webbiana*	12	71	85.5	3n	x		
62	Self-sterile mm N15	*2n B. procumbens*	18	85	82.5	3n	x		
63	US 35/2	*4n B. patellaris*	10	88	89.7	4n	x		

TABLE 1.—CONTINUED ON PAGE 219.

Table 1.—(Continued from page 218) F_1 Hybrids between Races of *Beta vulgaris* and Nematode-Resistant Species.

Progeny Number	Female Parent (*B. vulgaris*)	Pollinator	Number of Seedlings		Percent Hybrid Seedlings	Ploidy Level of F_1 Hybrids	Viability of Hybrids		
			Non-hybrid[1]	Hybrid			Lethal	Viable	Low Viability
4n Swiss chard:									
1	Lyon	4n *B. patellaris*	0	26	100.0	4n			x
3	Lyon	4n *B. patellaris*	71	3	4.0	4n			x
6	Lyon	2n *B. webbiana*	4	35	89.1	3n	x		
7	Lyon	2n *B. procumbens*	3	23	88.4	3n			x
10	Lyon	4n *B. patellaris*	17	32	65.3	4n		x	
11	Lyon	4n *B. patellaris*	65	5	7.1	4n	x		
12	Lyon	4n *B. patellaris*	0	32	100.0	4n		x	
14	Lyon	2n *B. procumbens*	4	11	73.3	3n	x		
15	Lyon	2n *B. webbiana*	4	18	81.8	3n			x
21	Lyon	4n *B. patellaris*	18	44	70.9	4n	x		
22	Lyon	4n *B. patellaris*	52	34	39.5	4n	x		
24	Lyon	2n *B. procumbens*	10	5	33.3	3n	x		
25	Lyon	2n *B. webbiana*	70	11	13.5	3n			x
28	Lyon	2n *B. procumbens*	6	4	64.7	3n	x		
30	Lyon	2n *B. procumbens*	27	0	0	3n	x		
39	Lyon	4n *B. patellaris*	6	45	88.2	4n	x		
40	Lyon	2n *B. webbiana*	18	52	74.2	3n	x		
44	Lyon	2n *B. procumbens*	0	5	100.0	3n	x		
56	Lyon	2n *B. procumbens*	32	64	67.0	3n	x		
57	Lyon	4n *B. patellaris*	15	0	0	4n	x		
60	Lyon	4n *B. patellaris*	10	72	87.8	4n	x		

The majority of hybrid seedlings were not viable, as usual. They died 3 to 5 weeks after germination. Some seedlings in the inviable group perished after having developed small second or third pairs of leaves. The mortality of hybrids was caused by poor development of their root systems. Seedlings which exhibited better root growth were able to develop a few leaves. From this background of high mortality, hybrid combinations showed different degrees of viability. A mating was classified as viable if a sufficient number of plants from the given combination developed to the flowering stage and were classified as low in viability when only a few plants grew to the flowering stage.

The following matings were viable: (a) Diploid progeny 17 (see Table 1) from hybridization of diploid Swiss chard × *B. webbiana*. (b) Triploid hybrids of three combinations with low viability. In these matings the majority of plants died in the seedling stage or after the development of a few leaves, but some hybrids grew well and became tall, vigorous plants. These hybrid combinations were tetraploid Swiss chard crossed with *B. procumbens* (progeny 7) and with *B. webbiana* (progenies 15 and 25). (c) Tetraploid hybrids derived from crosses of tetraploid Swiss chard (progenies 10 and 12) and tetraploid

Table 2.—Distribution of Viable Hybrids at Different Ploidy Levels.

Female Parent	Number of Matings	Number of Viable Progenies	Number of Progenies Low in Viability
Diploid matings:			
Sugar beets	8	0	0
Fodder beets	2	0	0
Red table beets	2	0	0
Swiss chard	6	1	0
Total	16	1	0
Triploid matings (1 genome *B. vulgaris* plus 2 genomes *B. patellaris*):			
Sugar beets	4	0	0
Red table beets	1	0	0
Swiss chard	5	0	0
Total	10	0	0
Triploid matings (2 genomes *B. vulgaris* plus 1 genome *B. procumbens* or *B. webbiana*):			
Sugar beets	6	0	0
Swiss chard	11	0	3
Total	17	0	3
Tetraploid matings:			
Sugar beets	8	4	0
Swiss chard	10	2	2
Total	18	6	2

sugar beets (progenies 8, 9, 19 and 31) with *B. patellaris*. Progenies 1 and 3 were low in viability and produced only 2 or 3 hybrids which grew to flowering.

Viability of hybrids varied at different ploidy levels (Table 2). In 16 diploid matings only 1 mating, involving Swiss chard, was viable.

In the triploids, 10 matings involving 2 genomes of *B. patellaris* were lethal. Triploid matings with 2 genomes of *B. vulgaris* gave 3 progenies of low viability when Swiss chard was used as a female parent.

Tetraploid matings were the most successful. Of 18 hybrid progenies 6 were viable and 2 were of low viability. The crosses in which tetraploid sugar beets were used as a female parent gave more viable progenies than the crosses produced with the tetraploid Swiss chard, and they did not contain lines of low viability which were observed in crosses to Swiss chard.

Viable combinations differed very strikingly from inviable ones. Many, if not all, seedlings in the viable combinations developed normally or almost normally from the first days of growth (Figure 1). Although their rate of growth was a little slower than that of non-hybrid seedlings, they exhibited fair root and leaf development. But even in viable combinations some plants gradually became retarded in development and died at different ages (some in the stage of 2 or 3 pairs of leaves and others after development of seedstalks).

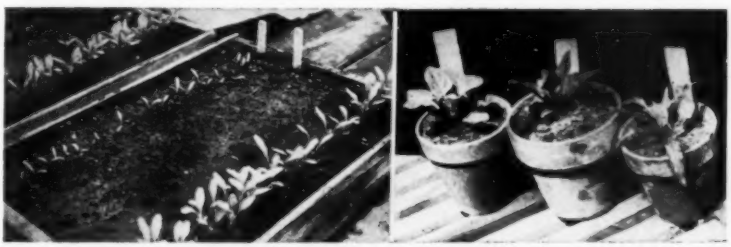

Figure 1. (left)—Hybrid seedlings from viable and lethal matings. Figure 2. (right)—Di-, tri-, and tetraploid hybrids at rosette stage (from right to left).

All viable plants from viable and low-viability matings were transplanted from flats into pots (Figure 2). They developed into vigorous, bushy, tall plants 7 to 10 feet tall or sometimes taller (Figures 3 and 4). There were 18 diploid hybrids, 5 triploids (sesquidiploids), and 62 allo-tetraploids (38 from sugar beets and 24 from Swiss chard) which reached the flowering stage.

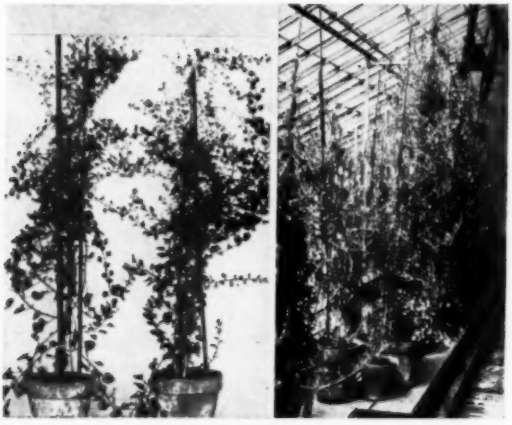

Figure 3. (left)—Two tetraploid hybrid plants at flowering stage. Figure 4. (right)—Tetraploid F_1 hybrids in the greenhouse.

The number of F_1 hybrid plants was increased by vegetative propagation.

The chromosome number in the hybrids derived from crosses in which both parents were diploids (progeny 17) was 18. From the triploid matings ($4n \times 2n$) all hybrids had 27 chromosomes (progenies 7, 15, and 25). Hybrids derived from crosses of $4n$ *B. patellaris* to $4n$ Swiss chard (progenies 10 and 12) or to $4n$ sugar beets (progenies 8, 9, 19 and 31) were all tetraploids with 36 chromosomes, with the exception of 2 plants among the hybrids with Swiss chard which were hypo-tetraploids with 34 and 35 chromosomes.

All hybrid plants, independent of the level of ploidy, had red hypocotyl, except 2 plants in the tetraploid progeny 19 which had white. One of these died at an early stage, another developed into a vigorous plant. This plant had 36 chromosomes. A possible explanation for the 2 white hypocotyl plants exists. Red pigmentation in *B. patellaris* is less intense than the pigmentation in *B. procumbens* or *B. webbiana;* therefore, it is highly probable that only one pair of chromosomes in *B. patellaris* carries the gene *R*. The gametes of *B. patellaris* would consequently carry only 1 chromosome with the *R* gene. Some gametes may not carry chromosomes with the gene *R* if random chromosome pairing exists or if a deletion at the *R* locus occurred. The F_1 hybrid plant with white hypocotyl could therefore have arisen from the union of a gamete of sugar beet and a gamete of *B. patellaris,* neither one carrying the gene *R*.

Diploid, triploid, and tetraploid hybrids differed in their appearance as well as in their rate of development. The first pairs of leaves in tetraploid hybrids were usually very chlorotic, almost yellow. In triploid hybrids the first leaves were green; in diploids the chlorophyll deficiency was intermediate between tetraploids and triploids. All fully grown hybrid plants were green and chlorophyll deficiency coud be noticed on young shoots only.

The shape of the leaf blade differed also (Figure 5). The leaves in tetraploid hybrids had a broad base like *B. patellaris,* but they were very large, even larger than the leaves of sugar beets. Part of this difference could be due to the *Patellaris* parent. The first pairs of leaves in several tetraploid plants were lobed and dissected (Figure 6). Sometimes dissections reached the central vein as in plants exposed to radiation. The leaves in triploid hybrids were also broad, but elongated, and in diploids they were long and narrow.

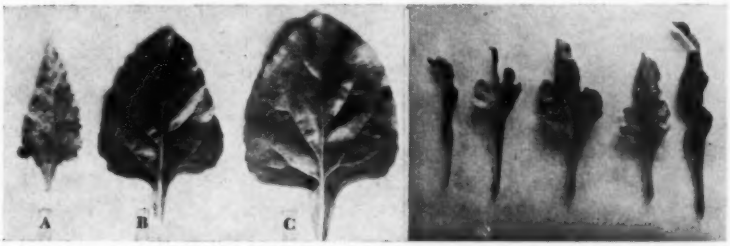

Figure 5. (left)—Shape of leaves in diploid (a), triploid (b), and tetraploid (c) hybrids. Figure 6. (right)—Lobed leaves in hybrids.

Hybrids at the different ploidy levels were distinguished also by their rate of growth and development. The tetraploids were most vigorous and started to develop seedstalks and to flower earlier than any other hybrids. The first hybrid to flower, a tetraploid, was 5 weeks old. One triploid plant started to flower almost at the same time; the others were later. The latest were diploid hybrids which developed slowly and started to flower at the age of 2½ to 3 months.

Wild beet characters dominated in all F_1 hybrids. They did not develop a fleshy root (Figure 7). All hybrids developed seedstalks and flowered abundantly the first year.

The anthers in diploid hybrids were small and unfilled (almost empty), failed to dehisce and were transparent to yellow. Some triploids developed completely transparent and empty anthers; the anthers in others were yellow and comparatively well filled. The well filled anthers dehisced and the stigma lobes

Figure 7. (left)—Root system in year-old tetraploid F_1 hybrids. Figure 8. (center)—A branching tumor hanging from the leaf. Figure 9 (right)—A branching tumor growing from a flower cluster.

when examined under binoculars were covered with pollen. Tetrapoid hybrids developed large, yellow, and comparatively well-filled anthers which did not dehisce.

Although parental plants involved in hybridization were always male fertile, the F_1 hybrids between *B. vulgaris* and all three species of the section *Patellares* developed male sterility independent of ploidy level.

Male sterility has been observed in several intergeneric and interspecific hybrids. It had been found in wide crosses in tobacco (2), wheat (9), Epilobium (12, 13, 14) and sugar cane (17). In these crosses male sterility was attributed to disharmony in the interaction between cytoplasm of species used as female and the genome of male parental species or to a reaction of special genes in the cytoplasm of another species.

Male and female sterility in the diploid F_1 hybrids (*B. vulgaris* $\times$ *B. procumbens* or *B. webbiana*) is a chromosomal sterility due to the meiotic chromosome disturbances and formation on non-viable gametes (21, 22, 23). The nature of male sterility in the tetraploid F_1 hybrids (*B. vulgaris* $\times$ *B. patellaris*) is unknown. Further investigations will reveal whether male sterility in these hybrids is also due to the chromosome disturbances or if it is associated with some other phenomena, possibly plasma-nucleus reaction.

All F_1 hybrids needed pollination by foreign pollen and were pollinated by diploid and tetraploid sugar beet plants distributed among hybrids.

Results of two seasons' data (1958 and 1959) indicated that fertility of hybrids differed depending on the level of ploidy. Diploid hybrids were completely or almost completely sterile.

Of 70 diploid plants only 2 plants set seed (6 seeds on one plant and 2 on another). Triploid and tetraploid hybrids were semifertile; they produced from 15 to 100 or more seeds. The degree of seed setting was conditioned not only by the genotype or polyploid hybrids, but also by the amount of pollen obtained by the different plants from the pollinators. At any rate, no one plant among triploid or tetraploid hybrids was completely sterile. Because of the continuous growth of hybrids, it is possible to obtain several hundred seeds from each plant. Hybrid plants have been trimmed from time to time and maintained for further seed production.

The first backcross hybrids obtained were varied; some resembled sugar beets while others approached more or less the type of F_1 hybrids. Some were dwarf or poor in development, while others developed into healthy, vigorous plants. Many were annuals and developed seedstalks after 3 or 4 months of growth.

Outgrowths were observed on several hybrid plants. These outgrowths started from tiny tumors on the leaf blades or from the flower clusters. Tiny swellings at the edges of the leaf blades developed into larger tumors which gave rise to thick, branching shoots. These shoots trailed from the leaves (Figure 8) or grew from the flower clusters alongside the stem (Figure 9). Sometimes numerous short, thick shoots developed from the same tumor forming a ball-like outgrowth (Figure 10). Such balls, 1 to 5 inches in diameter, hung down from the leaves of hybrid plants (Figure 11). These outgrowths were never observed on plants of pure species. They appeared spontaneously at the end of the growing season on diploid and triploid hybrids and, more often, on tetraploid hybrids. Certain genome combinations were possibly responsible for their appearance. These tumors were probably induced by unbalanced growth processes in interspecific hybrids. Tumors observed on *Beta* hybrids differed from genetic tumors in *Nicotiana* by their ability to branch.

Tumor formations have been reported in interspecific hybrids of *Nicotiana* by Kostoff (10), Kehr (7), and Kehr and Smith (8). Kehr suggested that tumors are induced by an abnormal balance of phytohormone in hybrid plants.

Morphology of flower, inflorescence, and fruit in species and hybrids

Inflorescence and fruit in the hybrids between the section *Vulgares* and the section *Patellares* have been described by most authors who succeeded in growing hybrid plants to the flowering stage. Although these descriptions reflected the author's

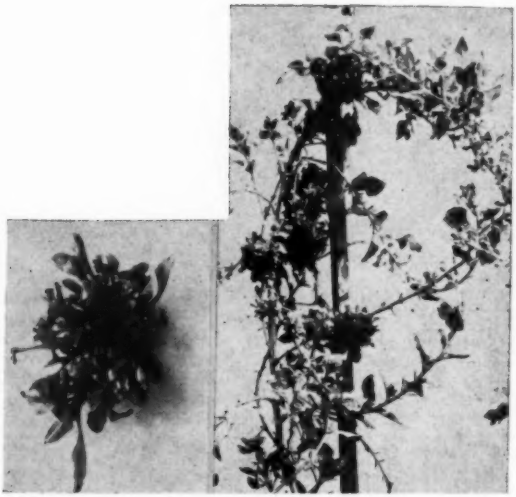

Figure 10. (left)—Ball-like tumor outgrowths. Figure 11. (right)—Ball-like outgrowths hanging on the leaves.

first impression of the hybrids, the structure of inflorescence and fruit was not sufficiently studied. Coe (3) found in grafted hybrids (sugar beet × *B. procumbens*) that flowers and inflorescences resembled sugar beets more than those of *B. procumbens*. Oldemeyer (15) indicated that in the F_1 hybrid *B. macrocarpa* × *B. webbiana* the flowers were borne in groups of 3, 4, or 5, similar to *B. macrocarpa*. Stewart (28) found that the fruit of F_1 plants (sugar beet × *B. procumbens*) was monogerm and resembled *B. procumbens*. There was a tendency for 2 or 3 seeds to adhere in clusters which could be easily broken apart. Johnson (6) indicated that seed in the grafted hybrids (sugar beet × *B. procumbens* and *B. webbiana*) resembled the wild parent more than those of sugar beets.

The general structure of the flower in the genus *Beta L.* is as follows: The calyx is composed of 5 sepals. Sepals have a narrow transparent stripe on the edges and a little hood at the top. The androceum consists of one whorl of 5 stamens. Stamens are located on a granular ring opposite every calyx lobe. The pistil is compound. The flower is perigynous (sepals and stamens are located around the ovary at the middle part of it). The ovary has a single locule. The ovule is campilotropous.

Flower structure in other *Beta* species deviates to some extent from this general pattern.

In the section *Vulgares,* and, consequently in the special *B. vulgaris,* the ovary is composed of 3 carpels, the free ends of which form 3 stigma lobes (2 or 4 stigma lobes which are sometimes observed, are derived from coalescence or from dissection of the original 3 lobes). The stigma is sessile, with lobes located directly on the ovary (Figures 12 and 13) and the central canal passes through the upper part of the ovary between the carpels. No style is formed.

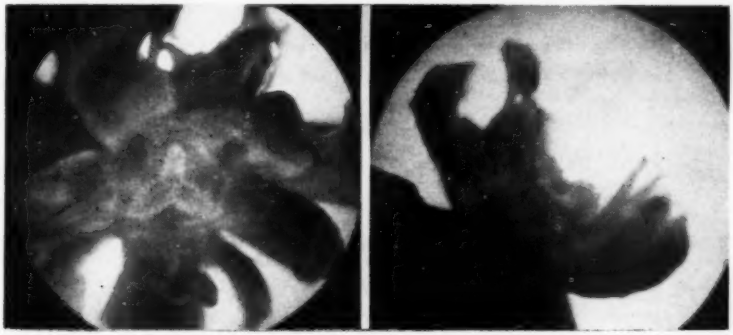

Figure 12. (left)—Stigma with 3 lobes in *B. vulgaris* (top view) X 10. Figure 13. (right)—Sessile stigma in *B. vulgaris* (side view) X 10.

Sepals, as described by Linne (11), Transhel (29), Hooker and Arnott (5), and Zossimovich (30), have a keel at the central vein on the back. In opened flowers the sepals are widely deviated and the anthers stand on stretched-out filaments in the middle of the flower; sometimes the tops of the anthers are hidden in the hoods of sepals and deviate together with them. At anthesis pollen is shed inside the flower and on the stigma lobes (self-pollination) (18, 19). Cross-pollination is effected by foreign pollen brought by wind and insects.

In all 3 species of the section *Patellares, B. procumbens, B. patellaris,* and *B. webbiana,* the pistil has a style with 2 stigma lobes (Figure 14). Evidently the ovary consists of 2 carpels only. In newly opened flowers stigma lobes are small and oval; in older flowers they become larger and elongated[4]. All species of the section *Patellares* have smaller flowers than those of the section *Vulgares.* Sepals are short (29, 30), without a keel on the back.

[4] Transhel (29), basing his studies on dry herbarium material, reported 2 or 3 stigma lobes in *B. patellaris,* but my observations on many living plants in all 3 species of the section *Patellares* during several years did not reveal plants or flowers with 3 stigma lobes. This observation coincides with the description of species in the section *Patellares* given by Moquin in De-Candolle and by Barker-Webb et Sabin Berthelot. The 2-lobed stigma is one of the most important characteristics distinguishing the section *Patellares* from other *Beta* sections.

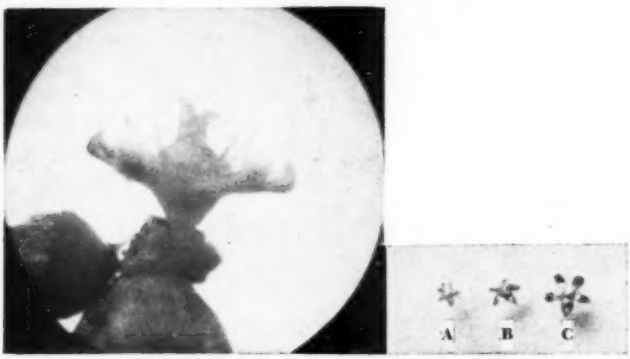

Figure 14. (left)—Stigma with style and 2 stigma lobes in *B. patellaris* (side view) X 10. Figure 15. (right)—Size of flowers in *B. patellaris* (a), *4n* F_1 hybrids *(B. vulgaris X B. patellaris)* (b), and *B. vulgaris* (c) X 10.

In other respects the structure of flowers and the mode of flowering in the species of the section *Patellares* resembles closely those in the section *Vulgares.* Flowers open wide; short anthers stand on stretched-out filaments in the center of the flower or deviate a little outwards and are seized by the hoods of the sepals. Pollen is shed inside the flower and on the stigma. The tops of the anthers never exceed the length of the sepals, a condition also typical for the section *Vulgares* and distinguishing the sections *Vulgares* and *Patellares* from the section *Corollinae.*

In the allo-tetraploid F_1 hybrids the size of the flower was intermediate between the size of the flower in the tetraploid *B. vulgaris* and that in the tetraploid *B. patellaris* (Figure 15). The buds and flower clusters of triploid and tetraploid hybrids exceeded the size of diploid hybrids. In hybrid plants the keel on the back of the sepals was more accentuated than in *B. vulgaris.*

All F_1 hybrids, whether diploid, triploid, or tetraploid, had two stigma lobes and developed a style. Rarely, a small third stigma lobe was observed. Sometimes the style was shorter and thicker than in the flowers of the section *Patellares* (Figure 16).

The inflorescence in the section *Patellares,* according to Savitsky (20), represents a panicle bearing umbels. In the section *Vulgares* (multigerm beets) the panicle bears multiple-flower clusters and later compound fruits or seedballs. The type of fruit in pure species and in hybrids naturally corresponds to the type of their inflorescences.

In flower clusters of multigerm beets in the section *Vulgares,* all flowers develop on a common peduncle. The upper part of the flowers from the base of the sepals grows over the peduncle

and gives an impression that each flower in a cluster is developing separately, but the lower part of the flower is not visible because the bases of the ovaries of all flowers are imbedded in the tissue of a cluster (formerly the upper part of a common peduncle) (Figures 17 and 21-a).

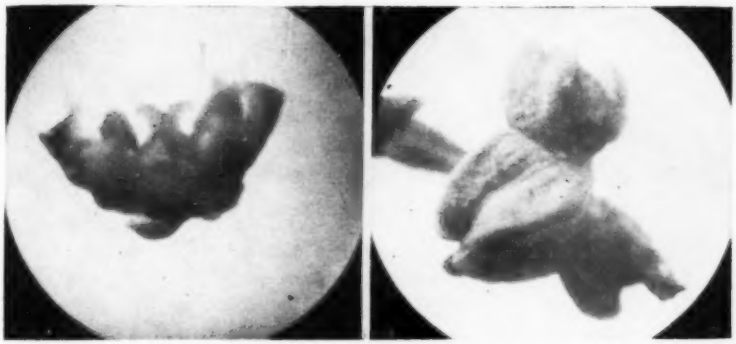

Figure 16. (left)—Stigma with style and 2 lobes in *4n* F_1 hybrids *(B. vulgaris* X *B. patellaris* X 10. Figure 17. (right)—Inflorescence of *B. vulgaris* X 10.

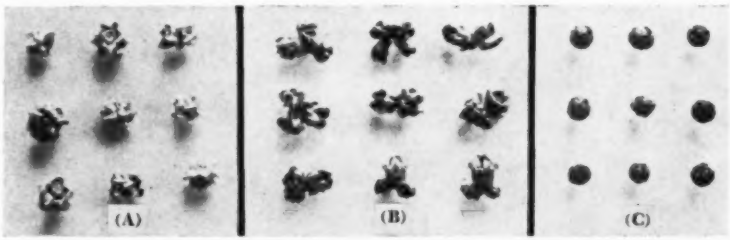

Figure 18.—Fruits of *B. vulgaris* (a), *4n* F_1 hybrids *(B. vulgaris* X *B. patellaris)* (b), and *B. patellaris* (c).

The fruits of multigerm races in the section *Vulgares* are compound (seedball). The bases of all ovaries, as well as all germs, are enclosed in a tissue of a seedball, and only the upper part of separate fruits is visible (Figures 18-a and 22). Separate fruits in a seedball look shorter, are flatter, broader, and bigger than the fruits in the section *Patellares.* Sepals are fleshy with clearly expressed keel. In some beet races the sepals exceed the cap a little leaving it open; in other races they exceed the cap considerably, covering it or bending over it. The tops of the sepals are narrow and shriveled to the vein.

In inflorescences of the section *Patellares*, all flowers in a flower cluster develop on a common peduncle also, but every

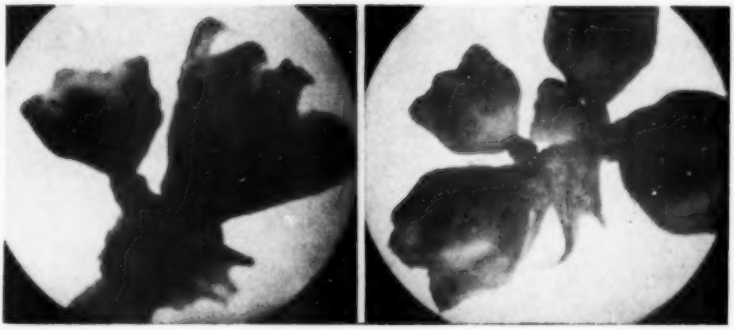

Figure 19.—Inflorescence of *B. patellaris* X 10.

flower develops its own little pedicel (forming the umbel) (Figure 19). In the central flowers of a cluster, pedicels are usually shorter and broader than in lateral flowers. In this way each flower develops separately, and the basal part of a flower, below the sepals, is visible as well as the upper part (Figures 19 and 21b). The type of the flower development in the section *Patellares* is similar to that in multigerm beets in that the flowers develop in a cluster from the same peduncle.

The fruit of species in the section *Patellares* is simple. The shape of the fruits varies from almost round to oval-elongated (Figure 18-c). Sepals are dry, pellicle, flat, without keel, and closely outline the fruits. The tip of every sepal carries an elongated dentation in the center at the upper end of the vein. Sepals do not cover the fruits, only the dentations of the sepals are adjacent to the cap, leaving the central part open. The only exception is *B. patellaris campanulata* Coss, in which the fruits are surrounded by the deviating tops of the sepals. After the fruits have ripened, the pedicels are broken and the single fruits shatter.

Species of the section *Patellares* do not bear true monogerm fruits because flowers develop in a cluster. True monogerm fruits are produced only by the species *B. lomatogona* Fisch. and Mey, and *B. nana* Boiss. and some races of *B. vulgaris* (24, 25).

The type of inflorescence in all hybrids (Figures 20, 21-c) is intermediate between the type of inflorescence of species in the section *Vulgares* and that of species in the section *Patellares*. In F_1 diploid, triploid, and tetraploid hybrids a flower cluster consists mostly of 3 or 4 buds; sometimes the number of buds reaches 6 or 7. Individual flowers in a flower cluster develop separately on a common peduncle like the flowers in a flower cluster of the

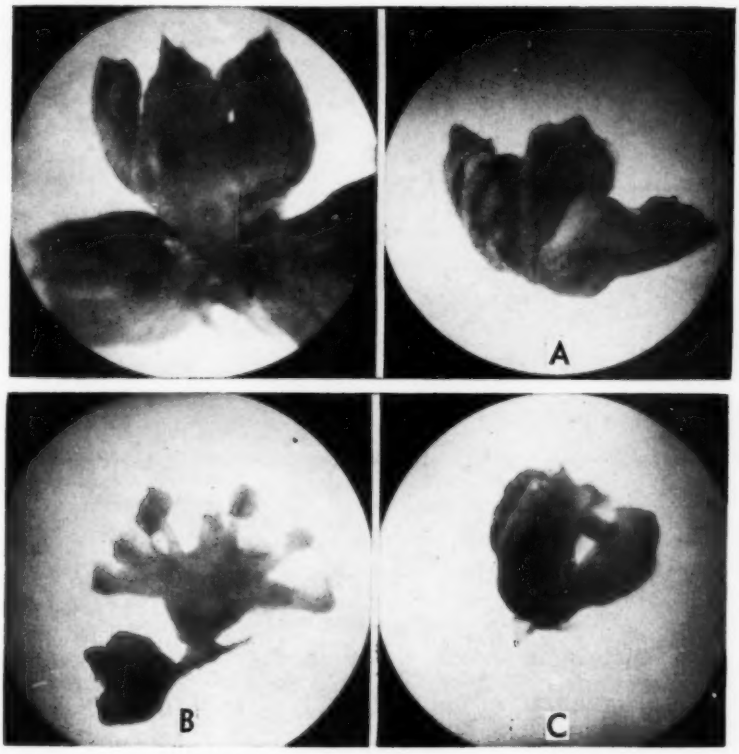

Figure 20. (upper left)—Inflorescence of 4*n* F_1 hybrids *(B. vulgaris* X *B. patellaris)* X 10. Figure 21. (upper right, A)—Shape of flower in *B. vulgaris* (lower left, B)—*B. patellaris* (lower right, C)— and 4*n* F_1 hybrids *(B. vulgaris* X *B. patellaris)* X 10.

section *Patellares,* but they do not develop the pedicels typical of the section *Patellares.* The basal part of a flower below the sepals is visible.

Fruits of F_1 tetraploid hybrids between *B. vulgaris* and *B. patellaris* are compound, consisting of 2 or 3 fruits, but they do not form a seedball. The basal parts of individual fruits are connected by the tissues of the common peduncle, but they are not imbedded in it (Figure 18-b). By applying some effort, fruits can be separated.

The basal part of individual fruits is oval or elongated, resembling the shape of fruits of *B. patellaris.* The sepals extend over the fruit, always covering the cap (Figure 23). The sepals

Figure 22—Fruit (a seedball) of *B. vulgaris* X 10.

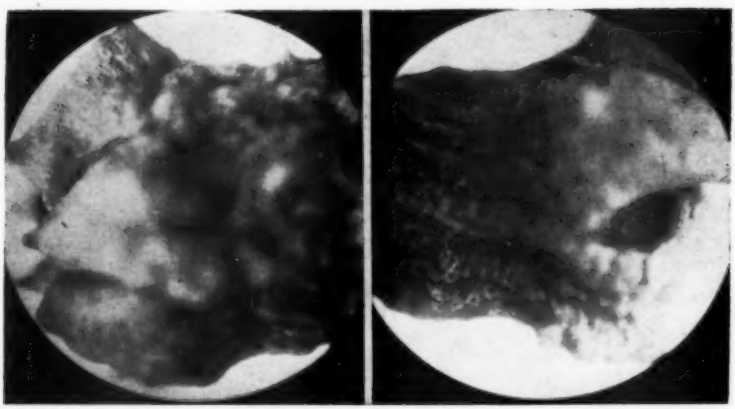

Figure 23.—Single fruits from clusters of 4*n* F_1 hybrids *(B. vulgaris* X *B. patellaris)* X 10.

are fleshy and the keel is expressed as in the section *Vulgares,* their tops narrowing gradually toward the center. Fruits of F_1 hybrids appear as if composed of fruits of both species, the lower part belonging to *B. patellaris* and the upper part to *B. vulgaris.*

Conclusion

Two ideas had been forwarded concerning the possibility of growing hybrid plants from crosses with species of the section *Patellares.* One consisted of grafting inviable seedlings. Johnson (6) and Coe (3) developed a successful technique for grafting. The other idea was the production of "bridge-hybrids" which

could be crossed to sugar beets for transmission of genes responsible for nematode resistance (4, 15).

Results of hybridization of different *B. vulgaris* races with three nematode-resistant species, *B. patellaris, B. procumbens* and *B. webbiana,* as reported in this paper, show that diverse viable hybrids with normal root development can be obtained if a sufficiently large scale of hybridization is used. Viable hybrids were not distributed at random among the hybrid material but were concentrated in certain hybrid lines; i.e., those belonging to certain mating combinations. Various *B. vulgaris* parents differed as to the viability of their hybrid progeny[5]. A larger diversity of genotypes involved in the hybridizations should provide better chances for obtaining viable hybrids.

Viable hybrids can be obtained not only by using the "bridge" represented by Swiss chard or different annual beets, but directly by crossing sugar beets with species of the section *Patellares.* Not all hybrid matings with Swiss chard were viable. Most of them, like most of the matings with sugar beets, were lethal. Only certain genotypes from Swiss chard populations, as well as certain genotypes from sugar beet populations, were able to produce viable or semi-viable hybrid lines, although it is possible that "bridge hybrids" may have a certain importance for diploid and triploid matings. In this experiment Swiss chard showed a somewhat higher ability than sugar beets to produce diploid and triploid hybrids with higher viability. For tetraploid matings, "bridge hybrids" are not necessary. Matings with sugar beets gave more viable hybrids in crosses with *B. patellaris* than Swiss chard.

For the first time viable triploid and tetraploid hybrids were obtained. More viable hybrids were obtained in polyploid than in diploid matings. These polyploid hybrids open new possibilities for hybridization between *B. vulgaris* and nematode-resistant species because it is easier to overcome the barrier of low viability and sterility at the higher ploidy levels. Cytological studies of F_1 diploid hybrids with *B. webbiana* and *B. procumbens* (21, 22, 23) indicated that diploid hybrids between the section *Vulgares* and the section *Patellares* are completely sterile unless they produce non-reduced gametes and a polyploid backcross progeny. Besides that, the offspring of diploid hybrids derived from non-reduced gametes (from asynaptic pollen mother cells) rarely if ever would carry chromosomes with segmental interchanges. Therefore, the necessity of producing diploid hybrids is very doubtful. It is simpler to obtain polyploid hybrids at once than to wait for occasional plants among diploid hybrids showing the

[5] Pollen of the wild beets was collected from the whole population.

ability to produce non-reduced gametes and polyploid progeny. It may also be probable that the transmission of genes responsible for nematode resistance will be more successful in polyploids than in diploids in which more chromosomes are involved in meiotic associations.

The way to obtain semi-fertile hybrids between *B. vulgaris* and species of the section *Patellares* with higher viability is now opened by the application of polyploidy.

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Effect of Soil Compaction on Development and Yield of Sugar Beets[1]

G. R. Blake, D. B. Ogden, E. P. Adams, D. H. Boelter[2]

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The object of this study was to observe soil and crop effects of deliberate and severe soil compaction in field plots.

Sugar beets are known to respond to desirable physical conditions (5, 10)[3]. Cook (4) found that packing of greenhouse pots reduced yield of beets more than tomatoes and much more than corn, soybeans, wheat, or oats. Joritsma (7) has shown the influence of soil structure on germination and root development. Rietberg (9) discussed this and other work in Holland showing that soil structure affects sprangling. He also stated that their work showed a negative correlation between early development of fangy roots and final yield. Also sugar content of fangy roots was lower than roots of good shape. Rietberg pointed out the disadvantages of sprangled beets in terms of difficulty of topping, high tare, and handling problems in the factory. He stated that several pests and diseases such as blackrot and wireworm are associated with poor soil structure but that it is not clear whether this is due to stronger parasite development or weakening of the beet.

Farnsworth and Baver (5) have shown that on fine textured soil beet yield decreased sharply as "non-capillary" pore space dropped below 8 to 10%. Pendleton (8) got unrestricted root growth at 14% and 18% air space on two soils but greatly restricted growth at 6.5% and 11.7% on the same soils in greenhouse pots. He found improvement in the shape of taproots as "non-capillary" porosity increased in field trials. Gaseous diffusion measurements in soils have led to acceptance of a tentative limiting porosity in field soils between 10% and 15% (1, 11). At values below this, gaseous diffusion approaches zero and root damage may occur even if these values exist only for short periods (2).

Guilbert (6) raised, but did not answer, the question: "Is there a possible correlation between the sugar content (of beets) and the compactness of the soil?" He found that high penetrability, owing to drouth or root pressure, promoted synthesis of

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[2] Associate Professor of Soils, University of Minnesota, Research Assistant, American Crystal Sugar Company, and former Research Assistants in Soils, University of Minnesota, respectively.

[3] Numbers in parentheses refer to literature cited.

sucrose. The question of whether high penetrability, or factors related to it, promoted sucrose synthesis is open to question as Guilbert indicated.

Methods

Plots were located at the American Crystal Sugar Company farm at East Grand Forks, Minnesota, on Bearden silty clay loam soil. This soil is formed on lacustrine sediments of prehistoric Lake Agassiz in the Red River Valley of the North. It is high in organic matter, 9.6%, decreasing with depth but extending 20-24 inches deep. It has excellent natural structure and, considering the flatness of topography and fineness of underlying sediments, internal drainage is generally good.

Sugar beets were grown in a rotation of potatoes, wheat-clover, clover-fallow, beets. Each crop appeared each year in a randomized block with six replicates. Recommended fertilizer rates were used uniformly on all plots.

The soil packing treatments were imposed on half of each plot each year before planting. In 1955 this consisted of surface packing by running a tractor weighing about 2800 pounds back and forth across the packed plots. A second treatment consisted of loosening the soil three inches deep in the bottom of each plow furrow. The check plot had neither packing nor loosening.

In 1957 and 1958 half of each plot was surface packed with a partially loaded truck driven across the plowed soil so as to cover the whole surface twice. The truck had a rear axle load of 15,010 pounds with an estimated applied pressure at the soil surface of between 60 and 100 pounds per square inch. The soil surface was dry and loose when packed but was essentially at field capacity below the surface few inches. After packing, the soil was dragged lightly before planting.

Regular field equipment was used for seedbed preparation, planting, and cultivating. At harvest, beets were hand topped after loosening with mechanical digger.

Aggregation was determined by a single-sieve wet sieving procedure. Air permeability was measured through metal cans driven into the soil. These were removed after the measurements for use in laboratory determination of porosity at 60 cm. tension and for bulk density by wax coating. Penetrometer determinations were made with a recording penetrometer.

Results and Discussion

Sugar beet yields were lowered by surface soil packing in both 1957 and 1958 (Table 1). In 1957 this amounted to 1.7 tons and in 1958, 4 tons per acre. The nearly three tons per acre average reduction on packed plots represented a 13% yield decrease.

Table 1.—Effect of Surface Soil Compaction on Sugar Beet Yields (T./A.)

Year	Not Packed	Packed	L.S.D. .05	L.S.D. .01
1957	23.5	21.8	NS	
1958	19.7	15.7	2.3	3.6

Only in 1958 was the yield reduction statistically significant at p. 0.05. However, in 1957, one replicate of six showed a higher yield (one T./A.) for compact soil. This is believed accounted for by the much higher population in this replicate with 31,100 vs 25,626 harvestable beets per acre. Over-all stand was not significantly different due to packing either year. On the other hand there may have been an accumulative effect of packing on yield due to annual packing, resulting in the greater yield decline on pack soil the second year.

Packing the surface soil much less severely in 1955 gave no yield differences. Nor did loosening the soil three inches in the bottom of each plow furrow affect yields over a nonpacked and nonloosened check.

Table 2 shows the extent to which packing affected soil physical properties when measured in midsummer. Percent

Table 2.—Effect of Surface Soil Compaction Prior to Planting on Soil Physical Properties in Late Summer.

Property	Not Packed	Packed	L.S.D. .05	L.S.D. .01
	1957			
Aggregation, %	15.8	16.0	NS	
Bulk density, gr./cc.	1.02	1.17	.03	.05
Aid permeability μ^2	54.1	12.8	28.5	—
Porosity, %, 60 cm. suction	14.9	8.4	1.4	2.3
Penetrability, lbs./inch^2				
6 inch depth	916	1160		**
10 inch depth	935	1175		**
	1958			
Aggregation, %	11.4	9.9	NS	
Bulk density, gr./cc.	1.06	1.16	.04	.07
Air permeability, μ^2	5.56	1.26	NS	
Porosity, %, 60 cm. suction	13.6	9.4	1.14	1.8
Cloddiness ratio*	0.42	0.57	0.15	
Penetrability, lbs./inch^2	54	105	10.6	16.6

*Ratio of clods to fines determined by 8 mm. sieve.

**Significant difference at .01 level.

aggregate stability was unaffected by the treatment. It is lower in all cases in this soil than one would expect from the high organic matter content. Nor did soil tilth appear to be poor probably due to flocculation resulting from a high $CaCO_3$ and $CaSO_4$ content (3).

Bulk density in the 1 to 4 inch layer was highly significantly affected by compaction. It averaged in the two years 1.04 and 1.17 for non-packed and packed plots respectively (Table 2). Subsequent studies have shown that packing affected bulk density to at least 18 inches. Air permeability in the 1 to 4 inch layer was lower each year on packed plots but was significantly lower only in 1957.

Porosity at 60 centimeters moisture suction, roughly equivalent to "capillary" pore space, was lower at the .01 level both years (Table 2). Averages for the two years show a reduction from 14.3 to 8.9 percent from packing. It has been shown (1, 11) that 10% to 15% air space is a threshhold for aeration. The shock due to lack of air at critical periods, when air space was lowest due to rain, possibly accounts for the lower yields on packed soil. Furthermore, the time, following rain, for air space to reach the critical 15% level would be greater on packed plots.

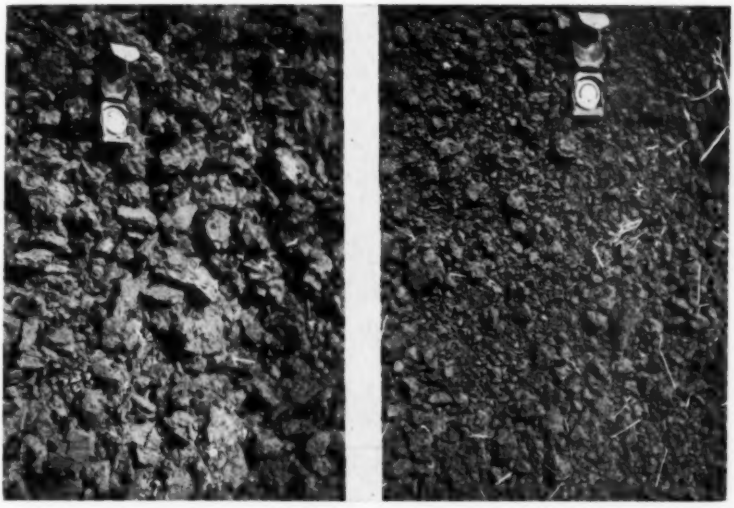

Figure 1.—Seedbed after plowing packed plot, left, and nonpacked plot right. Soil in left photograph had been packed 14 months and two months previously. Both were plowed and dragged just before photographs were made.

Penetrometer measurements show higher values on packed plots significant at the .01 level. Packed plots had a higher percentage of large clods in April 1958 (before 1958 packing) even after the wetting-drying and freezing-thawing action of the severe winter. Figure 1 shows a comparison of the soil surface of packed and nonpacked plots following plowing of sweet clover June 19, 1958. The packing treatment had been imposed in 1957 in a wheat crop and again in April 1958. Both were plowed and dragged just prior photographing. The unfavorable seedbed would be expected to seriously affect beet stands except for the fact that sugar beets were planted only after the cloddy surface weathered a year after packing.

Table 3.—Effect of Surface Soil Compaction on Sugar Beet Sprangling

Year	Not Compacted	Compacted	L.S.D. .05	L.S.D. .01
		Percent by Number		
1957	19.3	34.9	8.9	14.0
1958	15.3	38.5	4.5	7.1
		Percent by Weight		
1957	19.0	36.2	10.2	16.0
1958	18.2	41.5	10.7	16.8

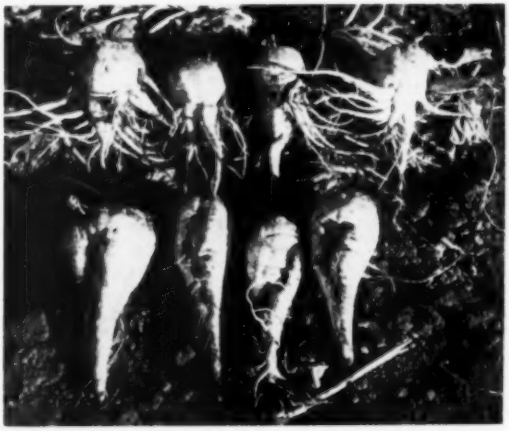

Figure 2.—Selected beets showing typical sprangled and non-sprangled beets.

Sprangling was noticeably more severe on packed plots (Table 3). Both percent by weight and number were higher on packed plots. A lower percent by weight than by number of sprangled beets would be expected if sprangled beets weighed less per beet. There is no indication that this is true. Figure 2 shows selected beets from packed and nonpacked plots.

Table 4.—Effect of Surface Soil Compaction on Percent Sucrose in Sugar Beets.

Year	Not Compacted	Compacted
1957	14.6	14.5
1958 Sprangled	17.6	17.6
Not Sprangled	17.9	17.7

Packing had no significant effect on percent sucrose in beets (Table 4). However, a separation of sprangled and nonsprangled beets gave an indication that sucrose content of sprangled beets may be slightly lower than nonsprangled. This effect, if real, confirms the finding of Rietberg (9) but is opposite to that inferred in the question raised by Guilbert (6).

Summary

Severe packing of the soil surface before planting reduced air permeability and percent of air-filled pores at 60 cm. moisture tension when measured in midsummer. Air space porosity on packed plots was lower than a commonly accepted threshhold value indicating this may have been a deciding factor in lowering yields and causing sprangling.

Sprangling was much higher on packed plots. Also sprangled beets had slightly lower sugar content though this was not statistically significant for packing treatment. Over all, beets on packed plots had a sucrose percentage about equal to those on nonpacked plots.

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A Continuous Sugar Centrifugal

FRANK PRICE[1]

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It is natural that, with the trend toward automation, efforts should be made to develop a machine which will continuously separate sugar from massecuite.

In 1957, it came to the attention of Mr. Silver that Hein, Lehmann & Co. of Dusseldorf, Germany, was manufacturing a continuous centrifugal which was meeting with some success in the European sugar industry. Mr. Silver was able to obtain the manufacturing and sales rights to this machine for the United States and Cuba.

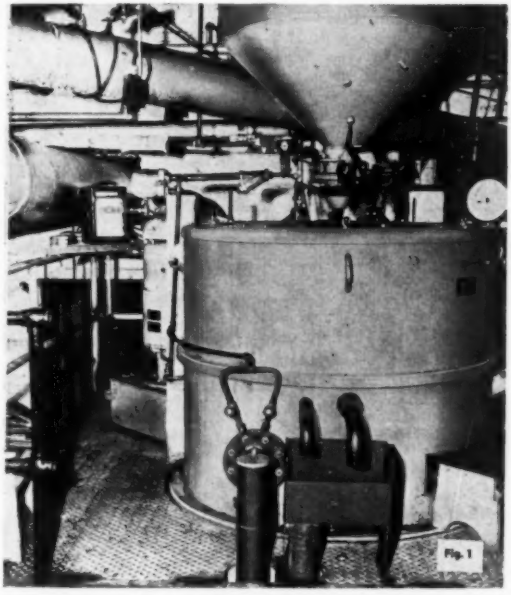

Figure 1.—The installation of a Hein, Lehmann centrifugal at the Nampa, Idaho, factory of The Amalgamated Sugar Company.

During 1958, a Hein, Lehmann centrifugal was brought over from Germany and installed at the Nampa, Idaho, factory of The Amalgamated Sugar Company. Figure 1 shows this installation. A series of test runs was made with this machine on both high raw and low raw massecuites. It immediately became apparent that the following changes would be necessary to make it acceptable to American practice.

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[1] Chief Engineer, Silver Engineering Works, Incorporated.

Three different size nozzles had been provided with which to control the flow of massecuite into the centrifugal. These had to be changed according to the viscosity of the massecuite, and this varied so rapidly that it was practically impossible to obtain good separation. This difficulty was overcome by the addition of an air operated valve on the massecuite inlet which is controlled through a transducer and Taylor controller receiving a signal proportional to the amperage of the centrifugal drive motor.

The Hein, Lehmann machine had no provision for separating a wash product from the green when operating on high raw massecuites, so another compartment for this product was added. After these changes had been completed, some extensive tests were made to determine the best operating conditions for this machine.

At the end of the campaign at Nampa, this machine was shipped back to Silver Engineering Works, an examination of all parts was made, and work was started on a design which could be manufactured in our shop. In addition to the incorporation in the new design of the flow control and the wash separation compartment, the over-all dimensions were changed to allow the machine to fit into a space which had been designed for a batch centrifugal; however, other than these changes, the basic Hein, Lehmann design was followed as closely as possible consistent with available shop tools and practices.

Figure 2 shows a cross section through the Silver Continuous Centrifugal. You will note that the machine consists of a rotating basket surrounded by three compartments; the inner compartment for green, the next compartment for wash, and the outer compartment for sugar. The wall of the inner compartment is adjustable in elevation so that the cut-off point between green and wash can be varied. Material collected in any of the compartments is transported from the machine by gravity. The rotating centrifugal basket is mounted on a vertical spindle which is V-belt driven by a 25 horsepower TEFC motor. Pulleys are provided to drive the basket at either 2000 or 2600 RPM.

The entire basket and spindle assembly is mounted on rubber blocks to dampen vibration should any unbalance occur. The ball and roller bearings of the spindle assembly are lubricated by a motor driven pump which continuously circulates oil through these bearings during operation.

Both steam nozzles and water nozzles are placed inside the basket so that either may be used to wash the sugar as it travels over the screen. Steam nozzles are also in both the green and wash compartments which can be used to steam out these compartments occasionally.

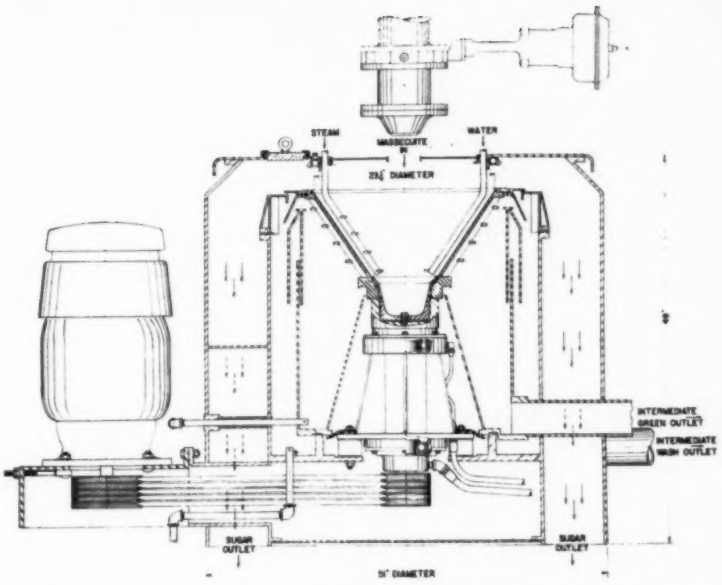


Figure 2.—A cross section through the Silver Continuous Centrifugal.

The basket is lined with a screen having perforations of 0.06 mm, or about 0.0024 of an inch wide. Screens with larger openings have been tried, but to date this is the largest size that is practical for American beet sugar massecuites. When the basket is rotating at 2600 RPM, forces of 800 g's and 2100 g's are acting at the small and large diameters respectively.

In operation, the massecuite is fed in a steady stream from the nozzle above the center of the basket. This flow is accelerated outward and upward as it comes in contact with the acceleration bowl at the bottom of the basket. As the massecuite flows out over the edge of the bowl, the syrup or molasses pass through the screen. The angle of the side of the basket has been selected so that the sugar crystals tend to cling without moving until they are crowded upward by crystals below them on the sloping side.

If the feed is stopped, the movement of the crystals across the screen is stopped. Consequently, the time that is required for a sugar crystal to travel across the screen is to a considerable extent a function of the quantity of massecuite being fed to the machine. The lower part of the basket will have a fairly

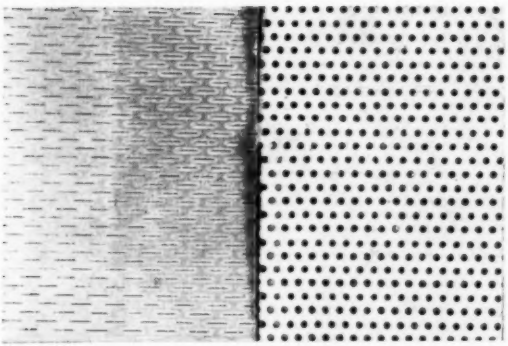
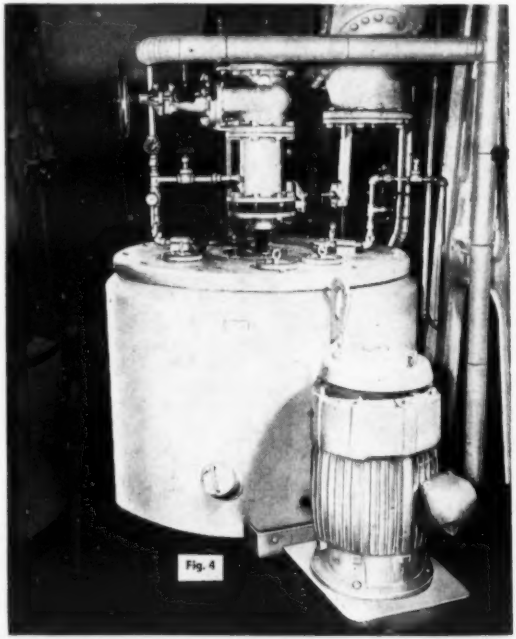


Figure 3.—A comparison between the screens on the Silver Continuous Centrifugal (left) and that used in a batch-type centrifugal (right).

thick layer of sugar which thins out as it moves upward until at the rim, it is probably no more than one-sixteenth of an inch thick.

Figure 3 shows a comparison between the screen used in the Silver Continuous Centrifugal and that used in a batch type centrifugal. The continuous centrifugal screen is about .008 of an inch thick. It is made by electrodeposition of pure nickel on a plate which has had the open areas masked to prevent deposition; in other words, the metal is built up around the hole. Electrodeposition requires a pure metal; of the pure metals, nickel is the most feasible for this purpose. The production of a screen with this size opening is undoubtedly one of the major steps in the development of the continuous centrifugal.

During 1959, Silver Continuous Centrifugals were installed at the Loveland and Johnstown, Colorado, factories of The Great Western Sugar Company and at the Nampa, Idaho, factory of The Amalgamated Sugar Company. Figure 4 shows the installation at Loveland. This machine is located in a space previously occupied by a batch type centrifugal. Figure 5 shows the installation of the machines at Nampa. The machines at both Loveland and Nampa were operated most of the time on high raw; however, the west machine at Nampa was piped up so that it could operate on either high or low raw and was occasionally used for low raw. Table 1 shows the test results obtained at Nampa with the Hein, Lehmann centrifugal during the 1958-1959 campaign. The capacity of the factory high raw machines during this campaign was approximately 4500 cubic feet per day, less whatever amount was put through the continuous machine.



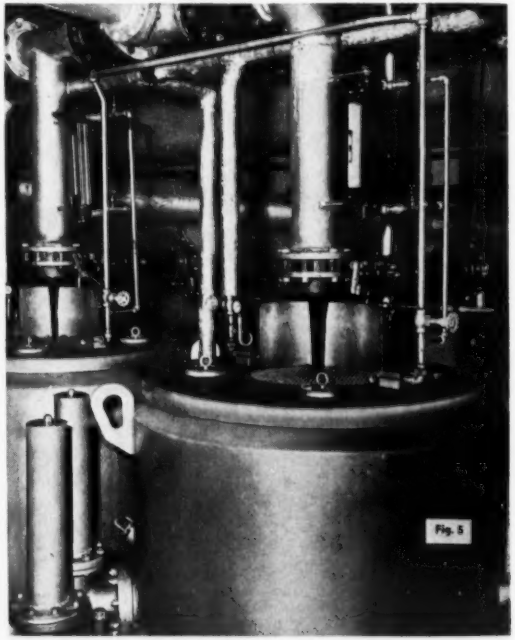


Figure 4.—(left) The installation of the Silver Continuous Centrifugal at the Loveland, Colorado, factory of The Great Western Sugar Company and Figure 5.—(right) the installation at the Nampa, Idaho, factory of The Amalgamated Sugar ompany.

Table 1.—Results of Tests of Hein, Lehmann Continuous Centrifugal During 1958-1959 Campaign at Nampa, Idaho, Factory of The Amalgamated Sugar Company.

Massecuite Tested	Number of Samples	Screen Opening Size mm	RPM	KW Input	Wash GPM	Massecuite Feed Rate Cu. Ft./Day	Apparent Purities						
							Massecuite	Continuous Centrifugal			Batch Centrifugal		
								Molasses or Green	Wash	Sugar	Molasses or Green	Wash	Sugar
Low raw	44	.06	2600	8.6	0.01	1027	79.2	62.7	.....	93.5	61.7	.....	92.8
High raw	27	.06	2600	16.2	1.7	3957	89.1	77.9	90.9	98.4	77.6	91.4	98.9
High raw	19	.06	2000	10.2	1.3	3993	88.8	76.6	90.2	98.4	78.2	89.9	98.8
High raw	8	.09	2000	10.5	1.6	4323	88.2	77.9	89.2	98.1	78.0	89.4	99.0

Table 2.—Ingenio Independencia, S.A. Martinez de La Torre, Vera Crus, Mexico, Results on "C" Massecuite with .06 mm Screen.

	"C" Massecuite		Continuous Type			Batch Type	
	Brix	Purity	Pol Sugar	Molasses Apparent Purity	Lbs./Hr.	Pol Sugar	Molasses Apparent Purity
Average of 53 samples of 13 days of operations from July 2, through July 15, 1959	90.75	66.02	92.17	43.96	7005	86.50	43.16
Average of 15 samples where apparent purity of molasses from continuous machines was less than that from batch machines	91.07	66.12	92.07	43.39	6347	87.23	44.26
Best individual run, July 3	89.80	65.06	93.30	44.65	5889	89.10	45.79
Best day, July 8	90.45	69.78	93.05	46.96	8345	89.34	47.26

After the original Hein, Lehmann centrifugal had been completely inspected upon its return to our plant, it was reconditioned and sold to Ingenio de San Cristobal Anexas, Mexico City. Table 2 shows a comparison of the results obtained with this machine and with their standard factory machines. This operation is in a cane mill on "C" massecuite. The product of this mill is raw sugar.

Table 3.—Results of Test Work on High Raw Massecuite Using Varying Amounts of Wash Water, Loveland, Colorado, Factory of The Great Western Sugar Company.

Wash Water Rate GPM	Massecuite Feed Rate Cu. Ft./Day	Apparent Purities			
		Massecuite	Green	Wash	Sugar
None	3000	87.7	77.0	77.9	95.5
0.35	3000	87.9	78.8	78.6	96.4
0.70	3000	88.3	79.1	79.3	97.0
0.90	3000	87.3	77.8	78.2	96.9
1.50	3000	87.4	77.7	78.6	97.5
None	4000	88.3	79.9	79.9	96.9
0.70	4000	88.3	79.6	79.5	96.9

Table 3 shows results of some test work done at Loveland during the latter days of the campaign. This centrifugal was being used throughout most of the campaign; however, when it was first put into operation, it was found to have a leak from the wash compartment into the sugar compartment through the seal at the top of the basket. A considerable amount of time was spent in trying various methods of checking this leak and it was, therefore, rather late in the campaign before any program of obtaining operating results on the continuous centrifugal was begun.

Tests consisting primarily of operating the Silver Continuous Centrifugal at a nearly constant rate and trying different quantities of wash, different location of spray nozzles, different locations of steam application, and different settings of the wash divider plate were made. However, the campaign ended before any changes could be put into effect from the evaluation of these results. You will note that the apparent purities of the green and wash do not vary greatly in these results. We believe that this is due to the design of the wash divider which allowed a flow of green into the wash compartment large enough in volume to obscure the results of the wash. This condition is being corrected.

Several tests of batch type centrifugals were made during the period operating information on the continuous centrifugal was

being gathered. These tests were made under closely controlled conditions. Water was applied 45 seconds after loading and total spin time after loading was 2 minutes. With a 6 quart wash, the purity was 97.83; with a 12 quart wash, the purity was 98.4; and with a 16 quart wash, the purity was 98.8. Under these conditions, the batch type machine showed a higher sugar purity.

Since Johnstown will be operating for several months, a test program on both "B" and "C" massecuites is planned at this plant.

Table 4 shows results of samples taken from the east machine at Nampa. This is the machine which ran continuously on high raw only. As mentioned previously, the screen used in this machine is made of pure nickel. This material is quite soft and, consequently, the wear life is not as long as desired. The life of screens on the east machine at Nampa is from 10 to 14 days. This machine is operating at a fairly high rate and is running approximately 90% of the time. We are at present working with a screen manufacturer to produce a screen of a harder material. This should not only increase the life of the screen, but should also allow more open area since the harder material will be stronger than the nickel. More open area, we feel, should increase the capacity of the machine. These new screens will be ready for service in the 1960 campaign.

Table 4.—Results of Samples from East Machine Operating on High Raw When 2 GPM or More of Wash Was Used. Nampa, Idaho, Factory of The Amalgamated Sugar Company.

Date	Control Set Point	Wash Water Rate GPM	Massecuite Feed Rate Cu. Ft./Day	Apparent Purities			
				Massecuite	Green	Wash	Sugar
12-2	32	2.3	———	88.6	78.8	92.4	99.3
12-5	35	2.3	3720	89.5	77.9	94.4	98.6
12-7	30	2.3	———	88.9	77.2	79.2	100.00
12-7	30	2.7	———	88.9	78.0	84.8	99.3
12-10	32	2.3	———	89.5	78.7	87.8	99.6
12-11	37	2.3	5350	89.9	81.0	92.1	98.7
12-15	40	2.5	6580	89.9	80.4	82.3	99.4
12-15	40	2.5	6580	89.9	80.9	82.8	99.3
12-15	40	2.5	6580	89.9	80.6	81.7	99.0
1-6	31	2.1	4600	90.2	80.0	87.4	99.1
1-6	31	2.7	4600	90.2	79.4	89.2	98.1
Average	—	2.4	———	89.6	79.3	86.7	99.1
Average of 16 samples from batch centrifugals from 10-15 thru 12-7		2.3	4500	89.6	79.2	91.7	99.8

Maintenance on the Silver Continuous Centrifugal has been negligible as would be expected from such a simple design. Belt life has been shorter than expected due to operating in an atmosphere of sticky vapors. In the future, this drive will be completely enclosed to prevent this condition.

The continuous centrifugals have all been located so that they are fed from the same mixer as the batch type centrifugals; hence, they have operated under conditions which are as close as possible to optimum for the batch type centrifugal. Since the two machines are so different in their construction and operating characteristics, it is a logical conclusion that possibly the operating conditions should not be the same. It seems desirable in the near future to make a set-up where the continuous machine is fed from its own individual mixer so that the temperature, viscosity, ET CETERA, can be varied and the results evaluated.

A comparison of the results in Table 2 with those in Table 4 demonstrates that the Silver Continuous Centrifugal will do as good or better than old and poorly operated batch type machines; however, modern, well operated batch type centrifugals will produce sugar of slightly higher purity. To offset this disadvantage is the practically supervision-free operation, the low power consumption, the low maintenance cost, and the low capital investment of the Silver Continuous Centrifugal.

Development of Monogerm Varieties of Sugar Beets by the Backcross Method

H. E. Brewbaker, R. K. Oldemeyer and H. L. Bush[1]

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Thirty-eight years have elapsed since Harlan and Pope (5)[2] reported the successful use of the backcross method in small grain breeding, and Briggs (3) initiated a similar project in wheat. Since that time, the backcross method has been used rather extensively by Briggs and Allard (4), Suneson (11), and others for self-pollinated crops. As applied to naturally cross-pollinated crops, Richey (6) used the backcross method in a convergent improvement program with corn inbreds, and Stanford (10) employed it in a disease resistance program in alfalfa. This method has been particularly useful for transferring a single character which is simply inherited. For sugar beets it appeared to be a desirable method for the incorporation of the monogerm (single locule seed ball) character into an established commercial variety.

Attempts to develop monogerm strains of beets by the U. S. Department of Agriculture as early as 1903 were unsuccessful. A monogerm character was reported by M. G. Bordonos (1) in 1941 as a simple recessive character. Brewbaker, et al. (2) in 1946 reported the isolation of genetic material characterized by a high incidence of 1- and 2-locule seed balls. This character was later found to vary in its expression with environment, and the material was dropped when the more stable monogerm material discovered by Savitsky (7) became available.

The backcross method was suggested by Savitsky (7) in 1950 for the introduction of the monogerm character into useful commercial varieties. In a later report, Savitsky (9) in 1952 outlined in detail possible techniques for the introduction of this character into commercial varieties. According to his suggested backcross plan, the monogerm plants from the segregating F_2 population, following the second backcross, would become the source of elite seed. Since the original monogerm SL 101 line is self fertile, and self fertility is dominant, his plan called for the selection and use of only self-sterile monogerm plants to make the second backcross.

The backcross method has been followed for the conversion of a Great Western commercial variety from multigerm to monogerm seed type. The first cross between GW304, a Great

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[2] Numbers in parentheses refer to literature cited.

Western leaf-spot resistant variety, and SL 101 was made in 1950, using two potted SL 101 plants supplied from the Salt Lake City station by the Sugar Crops Section of the United States Department of Agriculture. This cross was made by emasculation with a needle of flowers from 16 plants of the GW304 parent and hand pollination with pollen from the two SL 101 plants. For the first backcross the F_1 was used as a pollinator on GW304. Since SL 101 is self fertile and the GW parent self sterile, this backcross produced a population in which self-sterile and self-fertile plants occurred in a 1:1 ratio. The self-fertile plants were eliminated at this point so that self fertility would not appear in succeeding generations. A newly developed Great Western leaf-spot resistant variety (GW674) which was similar in origin but slightly superior to the commercial GW304 used for the original cross was used as the recurrent parent in the second and later backcrosses.

In order to proceed as rapidly as possible in this backcrossing program, each generation was artificially vernalized using low temperature and continuous light so that two generations a year were grown without selection except to recover the monogerm character in segregating F_2 generations. The segregation and approximate ratios for multigerm and monogerm for the generations succeeding the F_1B_1 are presented in Table 1.

Table 1.—Segregation and Ratio of Multigerm to Monogerm Plants in the F_2B_2 to F_2B_6 Generations.

	Multigerm (No.)	Monogerm (No.)	Total (No.)	Multigerm: Monogerm (Ratio)
F_2B_2	747	84	831	8.9:1
F_2B_3	1680	324	2004	5.2:1
F_2B_4	1492	198	1690	7.5:1
F_2B_5	1810	190	2000	9.5:1
F_2B_6 (Pop. A)	2075	521	2596	4.0:1
F_2B_6 (Pop. B)	1330	292	1622	4.6:1

The segregations of the F_2B_2 through F_2B_5 do not closely approach the 3 to 1 ratios obtained by Savitsky (8). This deviation from a 3:1 ratio has also been observed in the conversion of four other varieties. It would appear that modifying genes, in addition to or with greater effect than those Savitsky (7) has postulated for explaining the existence of a few doubles, were present in the GW commercial varieties used as the recur-

rent parents. In the F_2B_6 two different populations produced ratios of 4.0 and 4.6 to 1, respectively. These narrower ratios could be explained because the parental monogerm plants used to produce the F_1B_6 were carefully selected for freedom from doubles.

The backcrosses were made using pollen from one monogerm plant in the F_2B_1 generation, and for the succeeding generations a mixture of pollen was used from all available monogerm plants as shown in Table 1. About 200 plants of the recurrent parent were used for each backcross. The number of F_1 plants used to produce the segregating generations varied from about 200 in the B_2 to 600 in the B_5 and B_6 cycles.

The general procedure used in this backcross program is shown in Figure 1.

It will be noted from Figure 1 that six successive backcrosses have been made, and from Table 2, that tests have been conducted on monogerm varieties derived from the second to the fifth backcross. Since seed of SL 101 has not been available in quantity for extensive field testing, all comparisons of performance in replicated trials have been made only with the recurrent parent, GW674, with results as summarized in Table 2.

The results in Table 2 are summarized from variety tests with 12 replications of 54 feet of row per plot in 22 inch rows. Each test was conducted at two locations in 1958 and three in 1959 for the B_2 to B_5 generations in comparison with the GW674 parent; also for four observation plots for SL 101 in comparison with GW674 in the same series of plots. For yield of roots and

Table 2.—Mean Performance of Monogerm Backcrosses in % of GW674 in 5 Tests—Two in Colorado in 1958 and 1959 and One in Nebraska in 1959[1].

Variety	Yield of Roots	Sugar Content	Gross Sugar	Thin Juice Purity	Recoverable Sugar
GW674 MM	100.0	100.0	100.0	100.0	100.0
B_5 mm	101.7	100.4	102.1	99.8	101.8
B_4 mm	97.3	101.2	98.4	100.1	98.7
B_3 mm	94.1	99.1	93.4	99.8	92.9
B_2 mm	89.3	99.7	89.0	99.4	88.0
SL101[1]	48.8	104.3	51.0	.....	.....
LSD 5% pt.	2.7	1.2	2.9	0.4	2.9

[1] For SL 101, data are summarized from one observation plot in 1958 and three such plots in 1959.

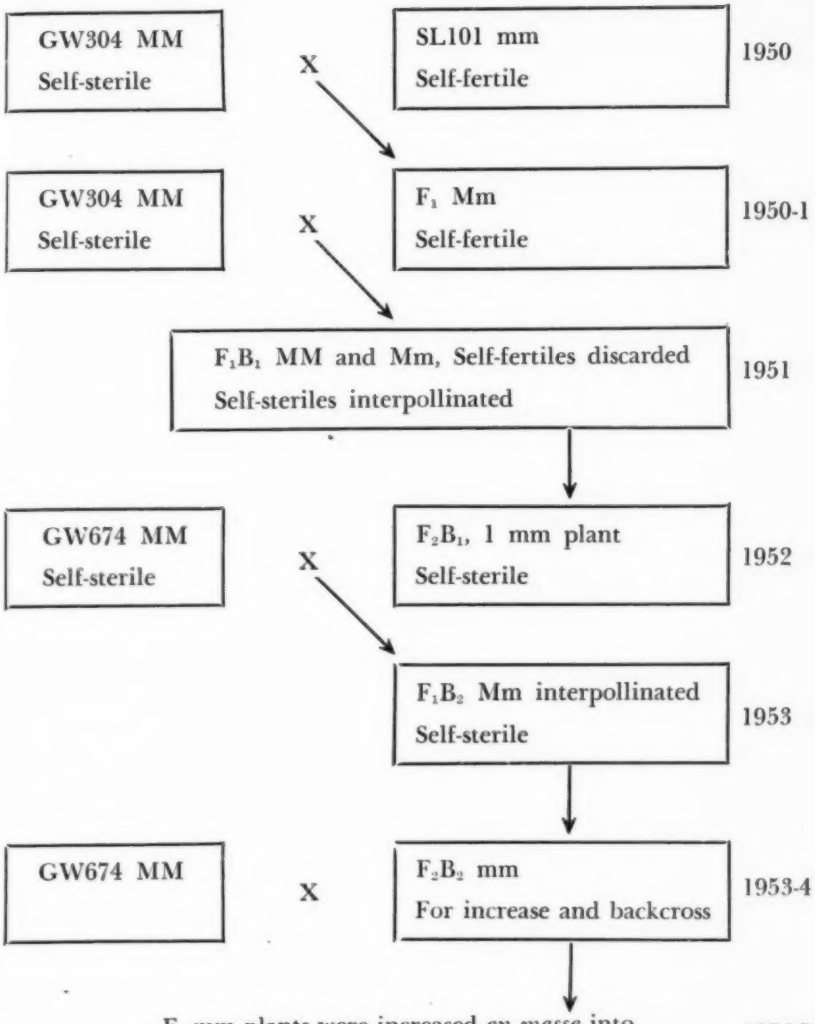

Figure 1.—Outline of procedure used for converting GW674 to monogerm by the backcross method.

total sugar, there appears, as expected, a gradual increase from the second to the fifth backcross. The monogerm character appears to have been successfully transferred to GW674 without loss in yield.

For sugar content, each backcross was statistically equal to the recurrent parent; however, the B_4 *mm* generation showed some possibility of a slight increase in sugar content above the recurrent parent. This was also true for the B_5 *mm* generation for two of the three replicated trials in 1958 with an average sugar content of 102.4 (% of GW674), which was significant at the 5% point. This trend of higher sugar content was also observed in one observation test plot in 1958 and three such plots in 1959 at as many separate locations in which the average sugar content was 104.4 (% of GW674). For this same series of observation plots, the average yield of roots in % of GW674 for the monogerm SL 101 parent was 48.8 and the average sugar content 104.3 (% of GW674). If further tests substantiate this apparent increase in sugar content over the recurrent parent, it may then be presumed that either an additional gene for sugar content has been acquired from the SL 101 monogerm parent and carried along closely linked to the monogerm gene or that the monogerm gene itself may have a pleiotropic effect on sugar content.

Summary

It appears that after crossing a GW commercial variety with SL 101 monogerm and backcrossing successively five times, the monogerm character has been successfully transferred to the GW parent without loss of yield or any other important character, and there is some evidence for a slight increase in sugar content over the recurrent GW parent. The backcross technique has proven to be very useful in transferring the monogerm character from a weak strain to a highly satisfactory variety for which commercial distribution has been made to growers, the whole project taking less than a decade for completion.

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The Role of Nitrites in Promoting High Ash Values in White Sugar

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Introduction

During the 1958 campaign, a beet sugar factory very suddenly had abnormally high ash values in its white sugar on two occasions. These two incidents, each lasting for several days, were about three weeks apart. Values of up to 0.166% conductivity ash were experienced. At times, an ash content of 0.017% was followed with a 0.111% value one hour later. Although this example was the extreme, there was no consistency in the conductivity ash readings. Extra-careful spinning and additional washing did not remedy the situation. An investigation was initiated to trace the cause of the high ash and to find suitable methods to avoid the reoccurence of abnormally high ash.

At about this time the research staff of the British Sugar Corporation published a series of *Studies in the Chemistry of Sulphitation* (1)[2]. In their attempt to establish a sulfur balance, Carruthers and co-workers reported an intriguing reaction mechanism that involved sulphites and nitrites which together form an end-product that was the real cause of some of their high-ash sugar. This end-product was proven to be a potassium salt of imidodisulphonate. Other researchers had found this compound in factory products on previous occasions (2).

In other publications Carruthers and co-workers reported on the *Nitrate Reduction by Thermophilic Bacteria in Sugar Beet Diffusion Systems* and *Activity of Thermophilic Bacteria in Sugar Beet Diffusion Systems* (3, 4). They definitely established bacterial activity as being the cause of nitrites in factory juices.

Results and Conclusions

In reviewing the findings of Carruthers and co-workers, together with the findings of this laboratory, the following results of this investigation are outlined to clarify the general relationship of nitrites in factory juices and high ash values in white sugar.

1. Nitrites are not native to the sugar beet.
2. Nitrites can be produced through reduction of nitrates by thermophilic bacteria.

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[1] Research Chemist and Research Laboratory Manager respectively, The Amalgamated Sugar Company, Twin Falls, Idaho.

[2] Numbers in parentheses refer to literature cited.

3. These thermophilic bacteria are soil borne and may flourish at relatively high temperatures at any place prior to sulphitation.
4. Nitrites so produced may react with bisulphites to form imidodisulphonate and sulfate.
5. Bisulphite is formed in significant quantities if the pH in the evaporation is below 8.0.
6. The dipotassium salt of the imidodisulphonate may co-crystallize with the sugar in the white pan if conditions favor its crystallization.
7. These conditions include:
   a. When the pH of the white pans is relatively low, i.e., less than 8.0, the less soluble dipotassium salt $HN(SO_3K)_2$ predominates. If the pH is well above 8.0, then the more soluble tripotassium salt $KN(SO_3K)_2$ prevails, causing the larger part of the imidodisulphonate to stay in solution and pass ofit into the molasses.
   b. The concentration of the imidodisulphonate has to be sufficiently high for co-crystallization.

The presence of imidodisulphonate was proven after this compound was isolated from high-ash sugar and identified according to the procedures of Carruthers and co-workers.

Table 1 shows the actual composition of an ash constituent isolated from high-ash sugar. The calculated value of theoretically pure di-potassium-imidodisulphonate and values obtained from di-potassium-imidodisulphonate prepared by synthesis are added for comparison.

Table 1.—Analysis of Ash Constituent from High-Ash Sugar.

	$HN(SO_3K)_2$ Calc.	Isolated from Sugar	Synthetic Salt
% Sulfated Ash	68.79	71.09	67.77
% Potassium	30.87	31.60	30.27
% Sulphur	25.32	25.25	25.33
% Nitrogen	5.53	5.72	6.00

Dividing the percent element in Table 1 by their respective atomic weights will yield the factor expressing the atomic ratio for this compound, in this case—1 Nitrogen, 2 Potassium, and 2 Sulphur, which corresponds with di-potassium-imidodisulphonate. Although the molecular weight of the isolated ash constituent was not determined, the typical appearance of the $HN(SO_3K)_2$ crystal could not be disputed. The isolated ash constitutent was purified by 3 times recrystallization in isopropanol.

Table 2.—Typical Daily Composites of High Ash Sugar.

	1-12	1-13	1-14	1-15	1-16	1-17	1-18
% Conductivity Ash	.008	.033	.027	.035	.021	.011	.007
% Sulfated Ash		.052	.036	.057			
% K in Sugar	.0028	.0122	.0102	.0136	.008	.0043	.0025
% S in Sugar		.0099	.0074	.0112	.0056		
% N in Sugar		.0061	.0056	.0082	.0028		

In Table 2 the actual presence of various elements in daily composites of high-ash sugar is shown.

A superficial examination of the values in Table 2 does not reveal exact stoichiometric ratios that one might expect if $HN(SO_3K)_2$ is the only ash constituent. However, the potassium sulfur ratio corresponds very closely to the ratio of pure $HN(SO_3K)_2$. The ratio of these two elements to the conductivity ash is slightly increased in favor of the conductivity ash. This shift must be expected. The nitrogen values are too high to account for the imidodisulphonate only. Apparently the ash contains proportionally more nitrogen with increasing ash content. Two possible explanations for the high ratios between the gravimetric ash value and the conductivity ash value are suggested:

1. The C-Ratio for conductivity ash calculation is not specific for these particular ash constituents.
2. An abnormal increase of non-ionized ash constituents which are not subject to conductometric determinations are evidently present.

By this time there was a high degree of certainty that the reaction mechanism as outlined by Carruthers and co-workers (1) was the principal cause of the high-ash sugar. Factory liquors were also analyzed for the compounds involved in this reaction.

Table 3 shows the amount of nitrite nitrogen in parts per million on dry substance in factory liquors when analyzed at the time of sampling.

The low nitrite values for station 1, 2 and 3 of Factory 1 indicate low levels of bacterial infection. The contamination begins at station 4 and spreads through station 5 for Factory 1. The reduction in nitrite content between stations 5 and 6 was rather large while the pH was low. This nitrite loss is an indication of the magnitude of the imidodisulphonate formation. The nitrite level remained about the same for the 2 p.m. and 4 p.m. readings for stations 1 through 5 of Factory 1. However,

Table 3.—P.P.M. Nitrite Nitrogen in Factory Juices.

Station		1	2	3	4	5	6	7	8	
Day	Time	Diff. Juice	1st Carb.	1st Press	2nd Press	Thin Juice	Thick Juice	Std. Liquor	High Green	
					Factory 1[1]					
1	4 p.m.	3.3	4	....	....	91	19	5	....	
1	5 p.m.	3.6	4	....	....	96	29	5	....	
2	8 a.m.	....	....	....	....	....	....	....	5	Low
2	9 a.m.	3.2	....	5.3	50	105	24	8	3	pH
2	10 a.m.	3.5	....	5.5	75	116	28	3	4	
2	2 p.m.	2.2	....	5.3	42	108	61	17	28	
2	4 p.m.	3.6	....	3.9	60	121	70	25	33	Higher
3	8 a.m.	....	....	....	....	....	....	....	5	pH
3	9 a.m.	1.7	....	1.1	9	38	7	4	4	
					Factory 2[2]					
1	2-3 p.m.	54.9	....	38.2	38	28	10	3	13	

[1] Factory 1 produced sugar with high ash.

[2] Factory 2 produced normal ash.

the decrease in nitrite between stations 5 and 6 was somewhat inhibited at higher pH's of the factory juices. The effect was not immediately seen in a low-ash sugar since large amounts of the imidodisulphonate were continually re-introduced from the raw side. In addition to that, there was still enough nitrite reacting to form excessive amounts of imidodisulphonate, but the ash in sugar was on the decline. The 9 a.m. reading on the third day reflects the measures to clean up the bacterial infection between the stations 4 and 5.

Factory 2 shows extensive activity of thermophilic bacteria at station 1. The nitrite level at station 5 is however within safe limits and the formation of imidodisulphonate is furthermore inhibited by relatively high pH of the factory juices.

The samples were taken from all stations at about the same time. Exact stoichiometric changes from station to station can not be expected for obvious reasons, but the general trend is definitely established.

Examination of the data requires a factory flow sheet to discover the head of bacterial infection. The sequence of the various stations at the beet end for this particular factory is in the following order:

A. Continuous Diffuser
B. Raw Juice Heater
C. Continuous First Carbonation
D. Dorr Thickener
E. First Press
F. Second Carbonation
G. Juice Boiler
H. Second Press
I. Sulphitation of Thin Juice

During the period of January 11 to January 18, 75 gallons of formaldehyde was added to the juice boiler to stop the bacterial infection there. The head of bacterial infection for the first high-ash period was not established. For the second period, when on the spot tests were conducted, the bacteria did survive all treatments through second carbonation to be reactivated in the juice boiler.

The unfortunate circumstance of using the juice boiler as a holding tank to adjust the flow without sufficient heating made this condition possible. As soon as proper corrections were made on the beet end, the quality of the sugar returned to normal.

Usually most of the bacterial activity is localized in the diffuser according to Carruthers and co-workers. These researchers report a close relationship between nitrate reduction, lactic acid production, and inversion in the diffuser. In fact, it is suggested that these processes are inter-related and caused by the same thermophilic bacteria (3, 4).

Temperature conditions in the beet end were investigated, but no deviation from normal could be observed.

In order to further follow the nitrite-sulfite reaction mechanism, composite samples of diffusion juice, first and second carbonation filtrates, thin juice, thick juice, standard liquor, and high green were collected at two factories. Three collections were made at one factory when the ash in white sugar was high, although not consistently high. Two collections were made at about the same time at another factory with low or normal ash values in white sugar. It is realized that these few samplings can not reveal the full complexity of the relationship between the interacting chemicals, factory conditions such as temperature, pH, bacterial infection, disinfection, etc. However, it is believed that a certain trend is indicated. The analysis consisted of the determination of nitrate nitrogen, nitrite nitrogen, and sulfate sulfur on diffusion juice, first and second carbonation filtrates. These analyses, plus surfite sulfur and imidodisulphonate sulfur, were made on all other factory products.

Table 4 is a typical comparison between Factory 1 which experienced high ash and Factory 2 producing sugar of normal ash content.

Table 4.—Analytical Comparison of Juices from Two Factories

	Diff. Juice	1st Press	2nd Press	Thin Juice	Thick Juice	Std. Liquor	High Green	
Nitrate—N	339	329	309	192	242	181	220	Factory 1
Nitrate—N	284	.....	328	243	254	198	306	Factory 2
Nitrite—N	4	5	103	121	54	19	20	Factory 1
Nitrite—N	62	.....	36	73	20	13	11	Factory 2
Sulfite—S	.....	.....	.....	220	183	201	251	Factory 1
Sulfite—S	.....	.....	.....	474	438	252	299	Factory 2
Sulfate—S	.....	268	260	404	467	302	535	Factory 1
Sulfate—S	413	.....	236	314	313	249	361	Factory 2
Imido-	.....	.....	.....	167	561	2064	2418	Factory 1
disulf—S	.....	.....	.....	121	189	127	213	Factory 2

Units: ppm on D.S.

In Table 4, the twenty-four hour composite of sugar at Factory 1 had a conductivity ash of 0.035%, with highs of 0.111% at 12 a.m. and 0.113% at 4 p.m. and a low 0.010% at 7 p.m.

It is surprising to find a significant amount of imidodisulphonate in thin juice. The conditions in the thin juice heaters are apparently sufficient to cause the formation of imidodisulphonate. The decrease in nitrite and sulfite and increase in sulfate and imidodisulphonate between thin and thick juice underlines the reaction mechanism as outlined previously. The enormous amount of imidodisulphonate amounting to about 1% on D.S. in Standard Liquor and High Green supports the reaction mechanism. Again, as in Table 3, the locality of nitrite formation is concentrated for Factory 1 somewhere between 1st presses and sulfur tower. Factory 2, although producing sugar with normal ash, shows again significant bacterial activity in the diffuser.

Relatively high levels of nitrite are not solely responsible for high ash sugar. The alkalinity in the evaporators has undoubtedly an effect on the kinetics of the nitrite-sulphite reaction. The average pH of thick juice for the high-ash period did not deviate from normal. However, during the first days of each high-ash period, the pH was lower than the average. Figure 1 shows the daily average pH trends of factory juices for one high-ash period.

These figures bear out the fact that the pH of thick juice was low enough to promote the formation of imidodisulphonate especially during the first days of each high-ash period. The relatively high pH level during the last part of this period undoubtedly help in overcoming the ash problem.

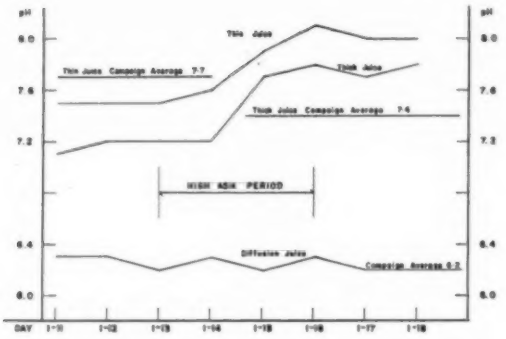

Figure 1.—Daily pH averages of factory juices.

In comparing the values of Figure 1, it is clearly shown that the pH of diffusion juice showed a very healthy level and makes a good showing when compared against the campaign average. The level is steady and not subject to fluctuation. Even the hourly readings did not deviate excessively from the average. The pH of thin and thick juice is shown to vary to a marked degree. Both curves run nearly parallel and start below campaign average at the beginning of the high-ash period. The rise of the pH during the high-ash period reflects the results of measures taken by operators to retard the sulphite-nitrite-imidodisulphonate reaction.

Both bisulphite and sulphite are present in factory juices after sulphitation. A pH of about 8 favors the sulphite but as the pH drops to 7 or less, the equilibrium is shifted in favor of bisulphite. Carruthers has shown that in the presence of nitrite the rate of imidodisulphonate formation is in the order of 1 to 72 as the pH drops from 7.7 to 6.3. It is obvious that unless a reasonably high pH is maintained through the white pans, the disulphonate formation can be serious if nitrites are present in the juice. Furthermore, each equivalent of nitrite nitrogen ties up three equivalents of sulfur, which means a loss of sulfur to the process.

However, the daily pH average may be grossly misleading in the face of highly fluctuating pH. Figure 2 shows the scope of the not-at-all-rare pH fluctuation in thick juice. Even though the average daily pH in thick juice may be as high as 7.8 or 8, there may be times when the pH will be less than 7.0. Fluctuations such as this should not be normal. Uniform operation and control of variables will do much toward the prevention of conditions conducive to high ash in sugar. What effect the bacterial

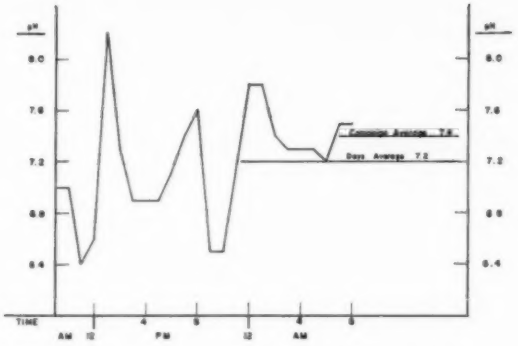

Figure 2.—Fluctuation of thick juice pH.

activity after second carbonation had on the fluctuating pH is subject to speculation. The extreme pH fluctuations may have been induced by the activity of thermophilic bacteria.

Figure 3 shows the typical relationship of white pan pH and white-sugar ash. The true picture is obscured by at least the following variables:

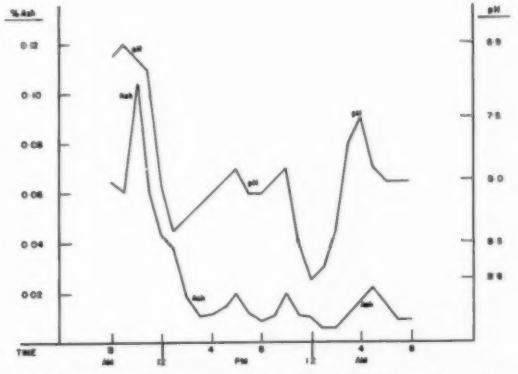

Figure 3.—Relationship between white fillmass pH and white-sugar ash.

1. The pH is taken directly from the fillmass prior to dropping the pan while the ash in the sugar is taken on an hourly basis on material in the mixture causing a carry-over from previous pans.
2. $BaCl_2$ was added to relieve the high-ash problem. This may indeed lower the conductivity ash, but may result in a higher gravimetric ash value.

3. Concentration of the imidodisulphonate in standard liquor will dictate the degree of its co-crystallization in the white pan.

Even though these variables may cause a slight shift in the true relationship of fillmass pH and sugar ash, Figure 3, nevertheless, represents some interesting relationships.

1. The negative correlation between fillmass pH and ash control of white sugar is very apparent.
2. The probability of producing unacceptable high-ash sugar is at least quite high if pH of the fillmass is kept below 8 in the presence of large amounts of imidodisulphonate.
3. White fillmass pH above 8 may greatly suppress ash in sugar but may not completely eliminate this problem in the presence of large amounts of imidodisulphonates.
4. A surprising point of Figure 3 is the human element. All the statistical material investigated established the fact that the second shift produced sugar with the lowest ash. They accomplished this by keeping the pH higher throughout the entire system.

Fortunately, it is only on rare occasions that a problem such as has been discussed develops. In any event, the margin of safety is increased by carrying the pH of juices and liquors at levels over 7.5 after sulfitation. By doing this, even if nitrites are present, the disulfonate formation is retarded because of a lesser amount of bisulfite, and if it is formed, the higher pH favors the formation of more soluble tri-potassium salt.

Summary

In summarizing the findings of this investigation, the following points are outstanding:

1. Sufficient bacterial control must be exercised on the beet end to keep the nitrite level low. This can be achieved by:
   a. Adequate high temperature. Not below 75° C. in the diffuser and not below 80° C. beyond the raw juice heaters to sulphitation.
   b. Extended storage of beet end juice prior to sulphitation at temperatures below 75° C. must be avoided.
   c. Proper usage of formaldehyde or other disinfectant.
2. If nitrites do occur at excessive levels, the pH of the evaporators should be kept above 7.7 to suppress the formation of imidodisulphonate. In addition to that, the pH of the white pan must be kept above 8 to curtail the co-crystallization of the dipotassium imidodisulphonate which might have formed in the evaporators. The pH of

intermediate and raw pans must likewise be kept high to discard the imidodisulphonate into the molasses.

To what extent other methods of bacterial and factory operations are involved remain to be investigated. Among these could be listed:

1. Chlorination of the beet wash water (Partially investigated by Carruthers) (4).
2. Degree of beet deterioration.
3. Locality of beet growing area and storage conditions are reported by Schneider and Hoffman-Walbeck (5) to be factors influencing bacterial activity in beets.

In any case, the most effective control of problems like this is in its prevention, not in its cure.

The objective of any factory operation should be the complete elimination of nitrite formation. One ounce of prevention is surely worth ten pounds of cure in this case.

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Chemical Control of Wild Oats (Avena Fatua L.) in Sugar Beets

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Although wild oats (*Avena fatua* L.) are not the most serious of the weeds bothering the sugar beet growers in southern Alberta, they do cause concern annually in a portion of the seeded acreage. The testing program began in 1948 at the Research Station, Lethbridge, Alberta, and was directed toward the control of wild oats and, to a lesser extent, green foxtail (*Setaria viridis* (L.) Beauv.) because most compounds available for trial use in sugar beets were primarily grass herbicides. By the end of 1953 it had been concluded that pre-emergence application of most chemicals was inferior to pre-planting, disked-in application, and since 1954 most of the herbicides included in the tests have been applied as pre-planting treatments.

Procedure

With the exception of 1956, tests were conducted each season from 1954 to 1959, inclusive, on a silty clay loam irrigated soil at Lethbridge. The plot areas were broadcast-seeded with wild oats in 1954 and 1958, in which years the resulting infestations were considered as seeded stands. In the other years of testing, further broadcast-seedings were made, resulting in what were considered as fortified natural infestations.

The following herbicides were included in this testing program for one or more years: isopropyl N-phenylcarbamate (IPC), isopropyl N-(3-chlorophenyl) carbamate (CIPC), dichloral urea (DCU), sodium salt of trichloroacetic acid (TCA), 2-chloro-N, N-diallylacetamide (CDAA), disodium salt of 3,6-endoxohexahydrophthallic acid (endothal), ethyl N,N-di-*n*-propylthiolcarbamate (EPTC), 2,3-dichloroallyl diisopropylthiolcarbamate ("Avadex"), and sodium salt of 2,2-dichloropropionic acid (dalapon). The selection for testing of these herbicides in any season depended on their potential performance as indicated by preliminary trials. Herbicide rates are reported as acid equivalent for TCA and dalapon and as active ingredient for all other materials.

DCU, in a wettable powder form, was applied with a single-nozzle, pressure-tank sprayer at solution rates varying between 160 and 320 gallons per acre. The other herbicides were applied with a boom plot sprayer at solution rates ranging between 13.2 and 22.2 gallons per acre in the different years.

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A split-plot design was used, with the herbicide main plots randomized within each of the four replicates and the application rate sub-plots randomized within each main plot. Sub-plots were 88 inches wide (four beet rows) and either 20 or 22 feet long.

Pre-planting applications were made during the first two weeks of May, except in the 1955 season when they were delayed until June 1, and the herbicides were immediately incorporated by two double-diskings at right angles to each other. Decorticated seed of Kuhn sugar beets was sown within one day of the pre-planting treatments. Post-emergence treatments were applied when the wild oats were in the 3- to 6-leaf stage of growth, at which time the sugar beets were in the early 2- to 4-leaf stage.

Control estimates of wild oats and, when possible, of green foxtail and broad-leaf annual weeds were made each year approximately six weeks after beet seeding. Quadrat counts of both wild oats and sugar beets were taken four and three weeks after crop seeding in 1958 and 1959, respectively. In 1959, after cultivation to leave an undisturbed 4-inch band along the beet rows, the thinning and weeding operation on each plot of three replicates was timed, one worker per replicate.

Yield samples were obtained by harvesting all beets in the center two rows of each plot. The numbers of beets were recorded, roots were washed and weighed, and rasped samples were retained for sucrose analysis. Sucrose analyses were made by the Sacks-LeDocte method as detailed by Brown and Zerban (2)[2].

Results and Discussion

A summary of the estimated wild oat control for the pre-planting herbicide applications is presented in Table 1. Quadrat counts taken in 1958 and 1959 indicated essentially the same degree of wild oat control as was estimated approximately two weeks later. The only notable exceptions were for the IPC treatments, where the counts indicated less wild oat stand reduction than did the control estimates, particularly in 1959 when the differences were from 18 to 22 percent for the various application rates. It was noted that a number of the wild oats in these plots were stunted and unthrifty when counts were made, and it is assumed that some of them died within the two-week period prior to making the control estimates. This observation seems to agree with the report of Nelson (7).

It is difficult to compare accurately a number of chemicals that were tested for a different number of years. However, a few observations are possible from the results of the pre-planting applications.

[2] Numbers in parentheses refer to literature cited.

Table 1.—Control of Wild Oats in Sugar Beets Obtained with Pre-planting, Disked-in Applications of Eight Herbicides. Lethbridge, Alberta.

Herbicide	Rate	Control[1]						
		1954	1955	1957	1958	1959	Avg. all Years	3-yr. Avg. 1957-59
	lbs./A.	%	%	%	%	%	%	%
IPC	4	69	82	91	81	69	78	80
	6	79	87	97	88	76	85	87
	8	—	—	96	92	84	91	91
CIPC	4	70	75	—	—	—	72	—
	6	71	80	—	—	—	76	—
DCU	5	34	0	25	—	—	20	—
	10	47	0	50	—	—	32	—
	15	—	—	56	—	—	—	—
TCA	5	—	—	56	—	—	—	—
	10	—	—	77	63	63	68	68
	15	—	—	85	79	73	79	79
	20	—	—	—	79	76	78	—
CDAA	4	—	—	70	28	56	51	51
	6	—	—	85	43	67	65	65
	8	—	—	92	53	80	75	75
Endothal	4	—	—	—	41	—	—	—
	6	—	—	—	47	—	—	—
	8	—	—	—	51	—	—	—
EPTC	2	—	—	—	—	89	—	—
	3	—	—	—	—	94	—	—
	4	—	—	—	96	96	96	—
	6	—	—	—	99	—	—	—
	8	—	—	—	99	—	—	—
"Avadex"	2	—	—	—	—	96	—	—
	4	—	—	—	—	98	—	—
	6	—	—	—	—	99	—	—

[1] Average of estimates taken of four replicates.

IPC at 6 pounds gave over 75 percent wild oat control in each of the five years, the control ranging from 76 to 97 percent and averaging 85 percent. The differences from year to year suggest that the results from this herbicide may be expected to be greatly influenced by such factors as soil cloddiness, soil moisture, and temperature.

CIPC was slightly less effective against wild oats than was IPC, as reported by Nelson (7), and CIPC gave a moderate degree of green foxtail control, whereas no control was evident from the IPC applications.

DCU, even at rates up to 15 pounds per acre, was relatively ineffective in controlling wild oats but gave good control of

green foxtail. This result does not agree with the results reported by others. For example, Nelson (6) reports good control of wild oats and volunteer small grain in Wyoming with 15 pounds of DCU.

Prior to 1955 TCA had proved ineffective as a pre-emergence treatment for wild oats at Lethbridge, though it showed some promise in controlling green foxtail. Pre-planting, disked-in applications of TCA gave slightly less than 80 percent wild oat control, with the 15-pound rate as effective as the 20-pound rate.

CDAA gave somewhat erratic control of wild oats. If at least 85 percent control is considered acceptable, then only the highest rate (8 pounds per acre) was satisfactory and in only one of the three years. Some control of green foxtail was obtained from pre-planting treatments with CDAA, but the control was less than for wild oats.

Endothal, though tested as a pre-planting application in 1958 only, was found to be an ineffective wild oat herbicide at rates of 8 pounds or less. Eckroth ET AL. (3) found endothal to give poor control of wild oats from pre-planting treatments, and Holst ET AL. (4) concluded that this material was of no value as a post-emergence treatment for wild oats.

The recently introduced herbicides EPTC and "Avadex" gave excellent control of wild oats at relatively low rates. Equally good control of green foxtail and wild oats was obtained with EPTC but "Avadex" was less effective for green foxtail. In addition, fairly good control of a mixture of lamb's quarters (*Chenopodium album* L.) and red-root pigweed (*Amaranthus retroflexus* L.) was obtained with the pre-planting treatment of EPTC at 3 pounds and "Avadex" at 6 pounds. From the limited testing of these two compounds, "Avadex" would seem to be the more useful in sugar beets if wild oats were the only, or the major, suspected weed pest, whereas EPTC would be preferred if a mixture of wild oats, other annual grasses, and broadleaf annual weeds was likely to infest a beet seeding.

It should be mentioned that, at the lower rates for which "Avadex" gave good wild oat control, barley and, to a lesser extent, wheat are relatively resistant to injury. All the other herbicides tested as pre-planting treatments will control volunteer cereal grains as well or almost as well as they control wild oats.

Some representative plots of several of the chemicals included as pre-planting treatments for the control of wild oats in sugar beets during 1958 and 1959 are shown in Figures 1 and 2, respectively.

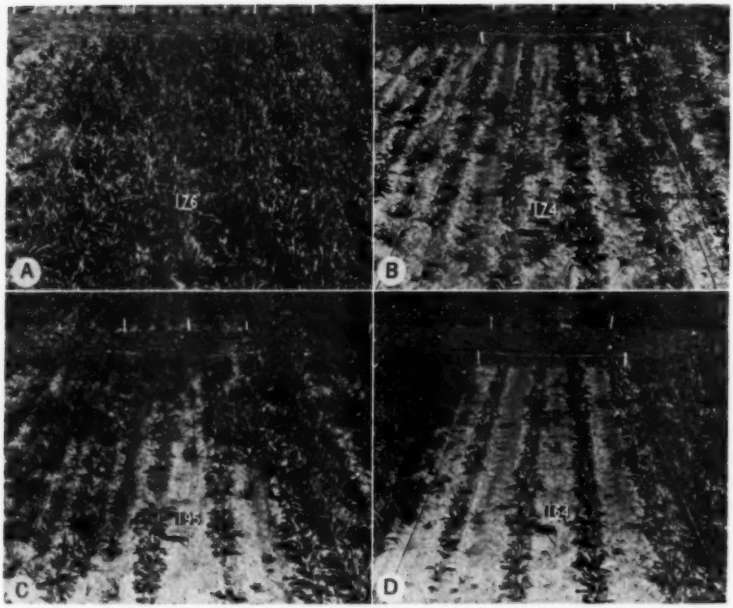

Figure 1.—Representative plots showing the amount of wild oat control obtained from pre-planting application of herbicides at Lethbridge, Alberta, in 1958. A, untreated check plot; B, IPC at 6 pounds per acre; C, endothal at 8 pounds per acre; D, EPTC at 4 pounds per acre.

Post-emergence treatments with TCA were made in 1957 and with dalapon in the years 1957 to 1959, inclusive. Most applications were made at a relatively late growth stage of the wild oats, as outlined previously, and no plants had been killed by the time beet thinning was carried out approximately two weeks later. In general, the full effects of the TCA treatments were evident within that time, but such was not the case for dalapon. TCA at the highest rate (8 pounds) gave only limited suppression of the wild oat growth, whereas the growth suppression resulting from dalapon was estimated to be 50 and 70 percent for the 4- and 6-pound rates, respectively. TCA was more effective in suppressing the growth of green foxtail than of wild oats, while dalapon appeared to be equally effective against both weeds.

The effect of the various herbicide treatments on the unthinned sugar beets was assessed visually prior to 1958. Of the herbicides tested as pre-planting treatments up to the end of 1957, only CIPC at 6 pounds and CDAA at 6 and 8 pounds

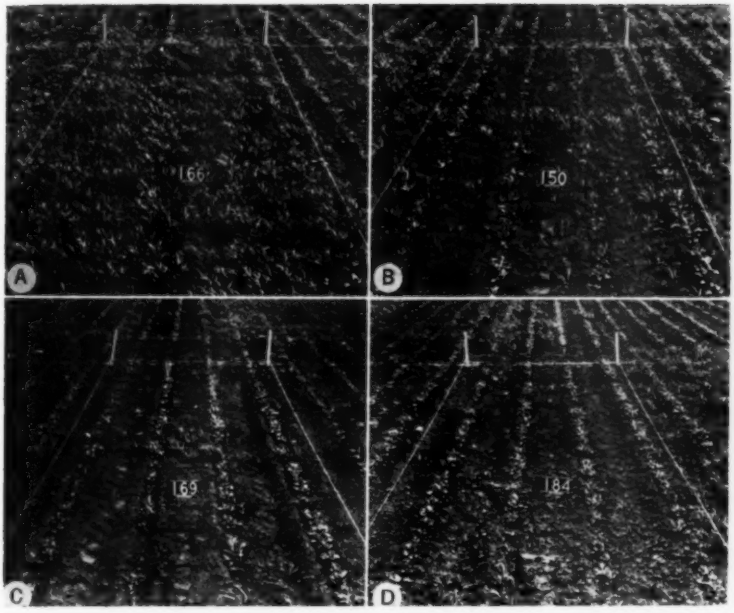

Figure 2.—Representative plots showing the amount of wild oat control obtained from pre-planting application of herbicides at Lethbridge, Alberta, in 1959. A, untreated check plot; B, IPC at 6 pounds per acre; C, EPTC at 2 pounds per acre; D, "Avadex" at 2 pounds per acre.

were deleterious to the unthinned beets. A slight stand reduction was noted from CIPC, and CDAA caused an evident, though not too serious, stand reduction and some delay in seedling emergence. The emerging beets on the CDAA plots showed some distortion, but the plants soon outgrew the defects.

In 1958 and 1959 quadrat counts of the beet stands were made. The 1958 counts indicated a wide divergence in stands, but the greater portion of the differences was probably due to the fact that stands were somewhat erratic and the stand counts were taken on too limited portions of the beet row lengths.

In 1958 very noticeable reductions of unthinned beet stands were evident from only the EPTC treatments at 6 and 8 pounds (Table 2). However, the 1959 data provided evidence that all the herbicides at the higher rates affected unthinned beet stands, being most serious for CDAA and least for TCA. The seriousness of a 40 percent stand reduction is related to the total population and stand uniformity. The unthinned

Table 2.—Effect of Pre-planting, Disked-in Applications of Six Herbicides on Unthinned Sugar Beet Stands. Lethbridge, Alberta.

Herbicide	Rate	Stand[1]	
		1958	1959
	lbs./A.	%	%
IPC	4	75	94
	6	85	74
	8	87	74
TCA	10	105	93
	15	105	87
	20	90	82
CDAA	4	100	75
	6	75	67
	8	96	57
Endothal	4	88	---
	6	88	---
	8	79	---
EPTC	2	---	95
	3	---	77
	4	85	73
	6	58	---
	8	55	---
"Avadex"	2	---	106
	4	---	100
	6	---	79

[1] Average of four replicates. Untreated checks—100%; 1958 counts—on four 10-inch row lengths per plot, 1959 counts—on four 5-foot row lengths per plot. Stand variation on a check set—25% in 1958 and 6% in 1959.

stand in 1959 contained nine plants per foot of row, and a 40 percent reduction still left an average of more than five beets. That number of beets was sufficient to give a 100 percent stand after thinning, which would be the case under field conditions unless herbicide treatment were to remove whole sections of the beet rows. That stand reductions of up to 40 percent were of no consequence was proved by the fact that beet root counts at harvest showed minor variations but none that were significantly different.

Post-emergence treatments with TCA at rates up to 8 pounds caused little or no visible injury to the unthinned beets. Dalapon, even at a rate of 4 pounds, caused some degree of leaf yellowing as well as a noticeable, though not severe, curling and slight browning at the leaf margins. This effect on the beets may have been the result of temperatures above 70° F., as it has

been shown by Warren (9) and Alley and Bohmont (1) that more injury occurs to beets at such temperatures.

The data obtained from the timing of the thinning and weeding operations in 1959 were of interest. It was found that, where a wild oat control of 90 percent or better was obtained from pre-planting treatments, the time required for thinning and weeding was reduced to approximately four-sevenths the time taken for the same operation in beets having a wild oat infestation of 195 plants per square yard.

Assuming 12 man-hours to be the time required for thinning and weeding an acre of relatively clean beets, which is less than the 16.9 to 18.9 man-hours estimated by Myrick and Huffman (5) for Montana conditions, the same job in the untreated wild-oat-infested beets would require 21 man-hours. In such circumstances, estimating a labor cost of one dollar per hour, a minimum of nine dollars per acre could be used to obtain 90 percent wild oat control with a herbicide.

A summary of the yields of sugar beet roots obtained during the test period is given in Table 3. No yield samples were taken in 1955 because very uneven beet stands were obtained in that season and, also, because the thinning and weeding were delayed excessively in order to assess the post-emergence treatments included.

Probably because of the relatively small plot size used in the tests, root yields were somewhat variable, and in no year were significant yield differences for individual pre-planting treatment rates established. However, it should be noted that in all but three instances the yields from the treated plots were greater than those from the untreated plots.

Considering the data for the three herbicides that were used in all three years 1957 to 1959, significantly increased yields resulted when pre-planting treatments with TCA at 10 and 15 pounds and with CDAA at 4 and 6 pounds were applied, but no significant yield differences were established for the rates of IPC. These facts are of interest because none of the TCA or CDAA rates gave acceptable wild oat control, whereas both the 6- and 8-pound rates of IPC did. Excellent wild oat control was obtained with all rates of EPTC and "Avadex" as used in 1959, and beet yields for all treatments except the 4-pound rate of EPTC were equal to or better than those for the untreated checks.

Sugar beet yields from the post-emergence treatments are given in Table 4. The yields were not adversely affected by any rate of TCA used in the one year of testing. Dalapon, tested as

Table 3.—Effect of Pre-planting, Disked-in Applications of Eight Herbicides on Sugar Beet Root Yields. Lethbridge, Alberta.

Herbicide	Rate	Yield[1]				
		1954	1957	1958	1959	3-yr. Avg. 1957-59
	lbs./A.	tons/A.	tons/A.	tons/A.	tons/A.	tons/A.
IPC	0	9.5	17.1	16.1	18.3	17.2
	4	10.4	19.7	17.6	19.2	18.8
	6	11.1	18.2	18.0	18.9	18.4
	8	.....	19.1	18.3	19.1	18.8
						N.S.
CIPC	0	9.4	.....	.....	.....	.....
	4	11.5	.....	.....	.....	.....
	6	10.1	.....	.....	.....	.....
DCU	0	10.4	17.2	.....	.....	.....
	5	10.3	17.2	.....	.....	.....
	10	10.6	18.1	.....	.....	.....
	15	.....	17.9	.....	.....	.....
TCA	0	.....	18.4	16.7	18.0	17.7
	5	.....	20.2	.....	.....	.....
	10	.....	20.3	17.9	19.3	19.2
	15	.....	19.7	19.1	19.0	19.3
	20	.....	.....	19.4	17.9	.....
L.S.D. (P = 0.05)						1.39
CDAA	0	.....	15.7	17.4	17.7	16.9
	4	.....	18.3	18.2	18.7	18.4
	6	.....	17.9	18.3	19.0	18.4
	8	.....	16.4	19.2	18.4	18.0
L.S.D. (P = 0.05)						1.18
Endothal	0	.....	.....	18.2	.....	.....
	4	.....	.....	19.3	.....	.....
	6	.....	.....	20.7	.....	.....
	8	.....	.....	19.8	.....	.....
EPTC	0	.....	.....	16.8	18.4	.....
	2	.....	.....	.....	19.4	.....
	3	.....	.....	.....	18.9	.....
	4	.....	.....	19.4	18.1	.....
	6	.....	.....	19.1	.....	.....
	8	.....	.....	18.6	.....	.....
"Avadex"	0	.....	.....	.....	18.4	.....
	2	.....	.....	.....	19.8	.....
	4	.....	.....	.....	19.9	.....
	6	.....	.....	.....	19.1	.....

[1] Average of four replicates.

Table 4.—Effect of Post-emergence Applications of Two Herbicides on Sugar Beet Root Yields. Lethbridge, Alberta.

Herbicide	Rate	Yield[1]			
		1957	1958	1959	3-yr. Avg.
	lbs./A.	tons/A.	tons/A.	tons/A.	tons/A.
TCA	0	16.6	.....	.....	.....
	4	17.1	.....	.....	.....
	6	18.1	.....	.....	.....
	8	17.4	.....	.....	.....
Dalapon	0	18.1	17.2	19.2	18.2
	2	18.2	17.8	18.5	18.2
	4	18.0	17.3	16.5	17.3
	6	18.2	14.6	16.5	16.4
L.S.D. (P = 0.05)					1.12

[1] Average of four replicates.

a post-emergence application for wild oat control over a three-year period, caused a significant yield reduction when applied at the rate of 6 pounds per acre and a trend toward a lowering of root yield at the 4-pound rate. These results are in general agreement with those of Southwick (8), who suggested that dalapon at rates above 5 pounds may cause some yield reduction, but they are at variance with the results of Alley and Bohmont (1), which showed no yield reduction resulting from a 6-pound post-emergence treatment with dalapon.

None of the herbicide treatments affected the sucrose content of the beets in any of the test years.

Summary

Results of tests conducted with a number of herbicides as pre-planting, disked-in applications for the control of wild oats in sugar beets over a period of five years are presented. IPC was tested in each of the five years, DCU, TCA, and CDAA for three years, CIPC and EPTC for two years, and endothal and "Avadex" for one year only. Limited testing of TCA and dalapon as post-emergence applications is also reported.

The only pre-planting treatments giving acceptable wild oat control of 85 percent or more were IPC at 6 and 8 pounds and all rates of EPTC and "Avadex." Moderately good control of wild oats was obtained with CIPC at 4 and 6 pounds, with CDAA at 6 and 8 pounds, and with TCA at 10 and 15 pounds. DCU and endothal, at rates tested, were considered to be relatively poor herbicides for the control of wild oats. CIPC, DCU, TCA, CDAA, and EPTC gave reasonable green foxtail control, and some control of broad-leaf annual weeds resulted from EPTC at 3 pounds.

Unthinned beet stand reductions of up to 40 percent resulted in 1959, but such reductions were insufficient to affect adversely the thinned stand.

Thinning and weeding time was reduced by three-sevenths when pre-planting herbicide treatment gave a wild oat control of 90 percent or more.

None of the pre-planting treatments caused a reduction in sugar beet yields. On the contrary, yield increases were obtained in most instances. Significant increases, based on three-year yield data, were obtained with TCA at 10 and 15 pounds and with CDAA at 4 and 6 pounds.

Post-emergence treatment with TCA at 6 and 8 pounds and with dalapon at 4 and 6 pounds per acre gave a measure of growth suppression of wild oats and green foxtail but did not kill the weeds within a two- to three-week period prior to hand weeding of the plots. Dalapon gave better suppression of wild oats than did TCA. Neither chemical affected beet stands, but dalapon at 6 pounds caused a significant reduction in sugar beet root yield.

No adverse effects on sucrose content of the beet roots resulted from any of the herbicide treatments.

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